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Surficial Geology of the Sawn Lake Region Alberta NTS 84B/13

Michelle Trommelen
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ABSTRACT

The Sawn Lake region is located within the northern boreal forest of Alberta, 37 km northwest of Red Earth Creek. The area is within the Western Canada Sedimentary Basin and Cretaceous bedrock locally outcrops. Kimberlite emplacement occurred between 86 ± 3 and 88 ± 5 Ma in the Buffalo Head Hills and sixteen kimberlites are found within the map area.

During the Late Wisconsin (marine isotope stage 2), the Laurentide Ice Sheet inundated the area, reaching a maximum around 23-24 ka BP. The ice deposited ice-advance gravel and basal till during its advance in a southwesterly direction. An older non-calcareous lower till was observed during drilling, capped by an upper calcareous till. The regional ice flow is locally substantiated by the K5 kimberlite south-southwest trending crag and tail and rare striae of azimuth of 215° on K6 kimberlite. Ice retreated to the northeast and the region was deglaciated by 10-11 ka, with deposition of minor glaciolacustrine sediment and significant hummocky ice stagnation (ablation) moraine. The stagnation moraine is found mainly within the uplands of the Buffalo Head Hills, forming undulating to hummocky terrain with regions of doughnut landforms. Glaciofluvial deposition likely occurred both during advance and retreat, recording subglacial eskers, tunnel channels, kames, kettles, and outwash plains. Ice marginal and proglacial outwash channels occur and there is evidence to suggest an earlier episode of subglacial fluvial deposition and flow across the map area. Later Holocene modification of the land has produced under-fit channels, minor erosion and deposition of organics in the lowlands and surrounding hummocky terrain.

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The Alberta Geological Survey, under the Alberta Mineral Development Strategy, funded fieldwork and aerial photographic interpretation in 2003 as a contribution to NRD Project 4450 (2003-2007). Roger Paulen and Jill Weiss supplied field assistance, advice, much discussion and critical review of the project. Field visits and sample data collected by Roy Eccles (1998), Mark Fenton (2001), John Pawlowicz (2002) and Glen Prior (2002) were made available to augment field observations.

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INTRODUCTION

The Sawn Lake region is located 37 km northwest of Red Earth Creek, Alberta, between 56° 45' and 57° 00' N, and 115° 30' and 116° 00' W (Figure 1). The area lies on the physiographic boundary of the Wabasca Lowland to the east and Buffalo Head Hills Upland to the west (Pettapiece 1986). Elevations in the map area range from approximately 820 m above mean sea level in the Buffalo Head Hills to 540 m in the Wabasca Plain Lowland. Local relief is low and some geomorphic features visible on air photos are negligible at ground level.

The region is heavily exploited for oil and gas, in addition to boreal forest clear-cut logging. More recently, active diamond exploration in the area provided the impetus for further geologic study. Surficial maps exist at scales of 1: 100 000 and 1: 250 000 (Paulen *et al.* 2003a; IN PRESS); this study provides a more detailed 1: 50 000 scale map. Because of extensive land use, the area is relatively accessible for ground-truthing stations. Thus, data was obtained from all quadrants to provide substantial lithologic data and strengthen map accuracy. To aid further construction in the region, the map delineates aggregate resource potential through identification of glaciofluvial deposits. This report focuses on the surficial geology of the region, providing a greater resolution for use in drift prospecting. In addition, the report provides an interpretation of lithology, stratigraphy and surface landforms and delineating the glacial history, including ice flow, of the Sawn Lake region.

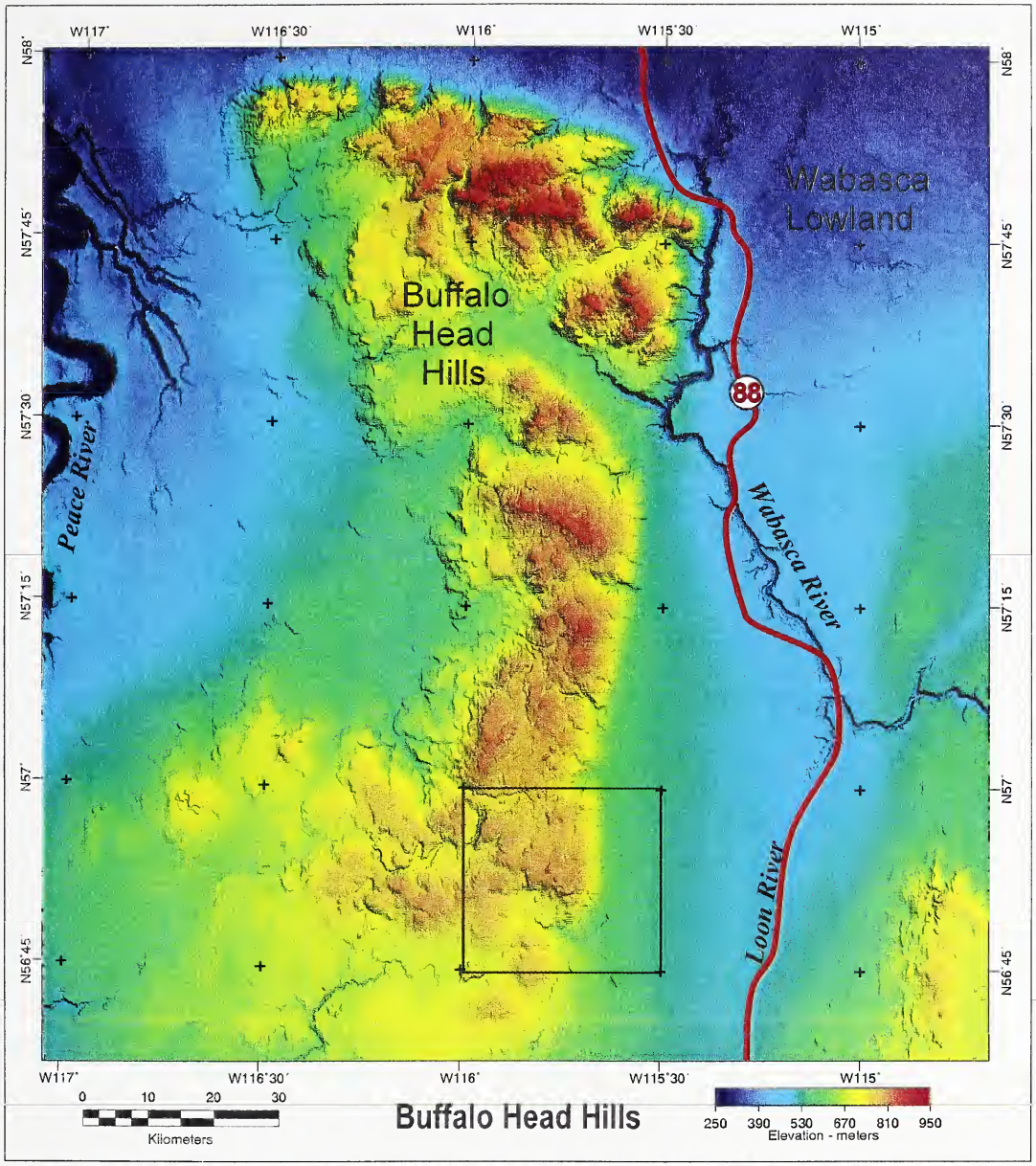


Figure 1. Digital elevation model for the Buffalo Head Hills, Alberta. Physiography of the uplands and lowlands is delineated. The black square denotes Sawn Lake map region NTS 84B/13.

PREVIOUS WORK

Soil surveys in the Peerless Lake region (Lindsay *et al.* 1957, Leskiw 1976) preceded hydrogeology studies by Cerocici (1979) and aggregate resource studies by Scafe *et al.* (1986; 1987). McPherson (1974) conducted the first surficial geology mapping in the region with later mapping at 1:100 000 scale by the Alberta Geological Survey (AGS) (Paulen *et al.* 2003a; 2003b; 2003c; Fenton *et al.* 2003a), and 1:250 000 compilation of NTS 84B (Paulen et al. IN PRESS). Adjacent areas to the west were recently mapped (Paulen *et al.* 2004) and the surficial geology to the north currently remains unmapped. Bedrock topography (Pawlowicz and Fenton 2004a) and drift thickness maps (Pawlowicz and Fenton 2004b) of NTS 84B were created through regional drilling and existing well log information (Pawlowicz and Fenton 1998, Pawlowicz *et al.* 1999). Kimberlite indicator mineral anomalies were discovered in 1996 as part of a regional indicator mineral sampling program (Fenton and Pawlowicz 1997; Pawlowicz *et al.* 1998). Recent studies of diamond potential for the region (Eccles *et al.* 2001, Prior *et al.* 2003) will be augmented with a collaborative AGS-Geological Survey of Canada (GSC) study of kimberlites and dispersal train studies as part of the Northern Resource Development (NRD) project 4450 (2003-2007).

METHODS

The principle objective of this project was to produce a detailed (1:50 000) surficial geology map of the Sawn Lake region (NTS 84B/13). Aerial photograph interpretation at 1:20 000 and 1:40 000 scale was completed to obtain a detailed preliminary map of the surficial geology. Heavily forested and inaccessible areas were mapped only by air photo interpretation, while accessible areas were ground checked during the 2003 field season

Figure 2. Methods used during mapping. A) Burrow pit exposures (new and old) with an average depth of 3-6 metres. B) Road cut section through ridge. C) 2 metre long Oakfield soil probe. D) 1 metre long Dutch auger.

along roads, seismic lines, pipeline routes and well sites using a truck, all terrain vehicle and helicopter. Where possible, existing burrow pits (created during road and well site construction) were used for identification of surficial materials (Figure 2A). These pits range from 2-6 m in depth and up to 50 m in width. Newly cut ditches and road cuts were also used, exposing an average of 1 m for the former and up to 6 m for the latter (Figure 2B). In areas where exposures were not available, stations were established using an Oakfield soil probe (Figure 2C) or a Dutch auger to a depth of at least 1 m. Care was taken to ensure that stations near well sites and roads were placed away from areas of potential human disturbance. This field data was then merged with existing stations obtained during earlier AGS mapping and kimberlite indicator mineral sampling and subsurface data was obtained from recent AGS trenching and borehole work and a station map was compiled (Figure 3). The density of these stations provides mapping confidence for the region, with an average of 39 sites per 10 km^2. Approximately 60% of the polygons were evaluated, providing a high level of reconnaissance information for the region. The aerial photograph interpretation was then compiled on a 1:50 000 scale mylar base map and digitized by the AGS.

A sample of ~ 25 pounds was taken from the gravel at site MT03-005, 50 cm below the upper till contact. At the lab, the sample was washed and sieved using sieves # 3.5, 4 and 10 to separate the sample into size fractions of > 5.66 mm, 4.76 < x > 5.66 mm, 2.00 < x > 4.76 mm and > 2 mm respectively. The two larger fractions were then classified and counted according to lithology.

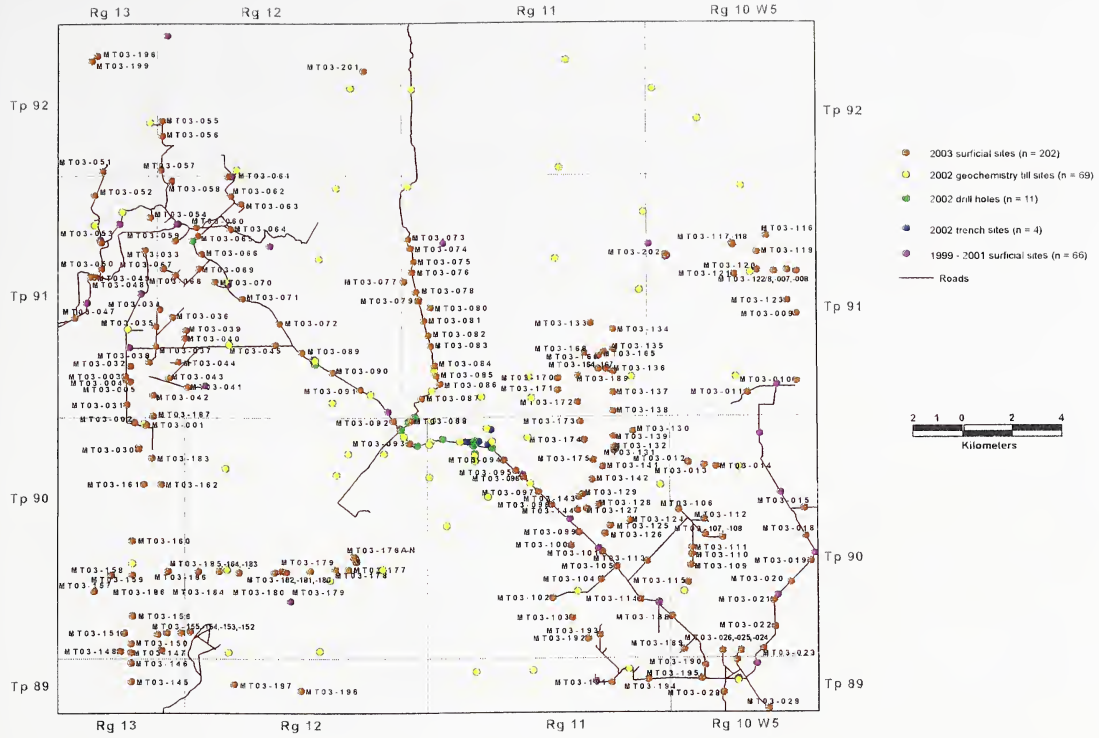


Figure 3. Station map denoting fieldwork completed at various stages and complied together.

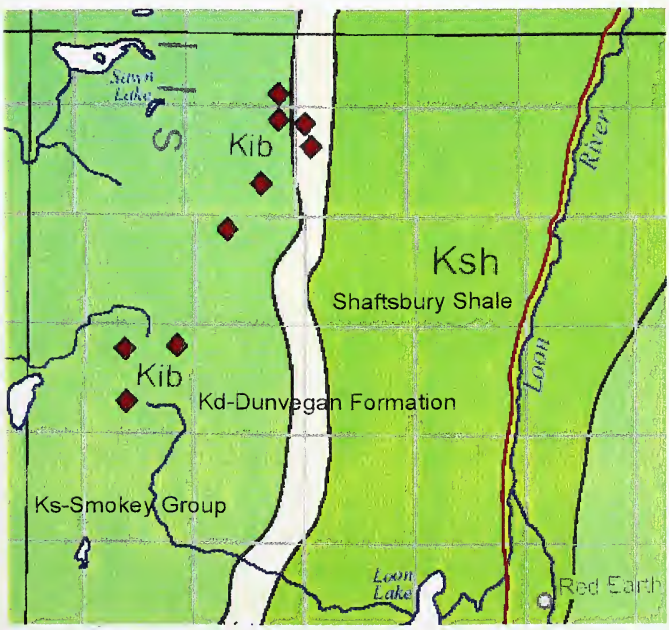


Figure 4. Map of bedrock for the NW Buffalo Head Hills. Map area is in upper left corner. All formations/groups are Lower to Upper Cretaceous. Kib stands for kimberlites known at time of map creation. Hamilton *et al*. 1998.

BEDROCK GEOLOGY

The map area is part of the Western Canadian Sedimentary Basin and includes outcrops of Cretaceous age mudstones and sandstones (Hamilton *et al.* 1998; Figure 4). The region is void of structural elements, and is essentially flat lying. Outcrops of sandstone and shale bedrock occur in the Buffalo Head Hills and have been dated as Late Campanian age using palynology (site MT03-161, Eccles *et al.* 2001). This places the sandstones and shales within the Wapiti formation, which is younger than the mapped Smoky Group (Hamilton *et al.* 1998).

Bedrock outcrops were encountered at site MT03-001, -002 and -161. Sites MT03-001 and -002 are burrow pits that expose fissile grey shale and ironstone sharply overlain by a 1.5-3 m veneer of till. Site MT03-161 is also a former burrow pit, exposing sandstone and mudstone overlain by a thin veneer of till (Figure 5).

A jawbone (Figure 6 A, B) discovered during the course of fieldwork (MT03-069), belonged to a Cretaceous ichthyosaur, likely *Platypterygius* (Figure 6 C, D; Darren Tanke, pers.comm. 2003). The bones were found within a road cut till hummock and allude to the marine nature of nearby bedrock outcrops. The jawbone was likely sourced from the Shaftesbury Shale (Figure 4) to the northeast, which fits stratigraphically with *Platypterygius* fossils found in the Clearwater Formation at Fort McMurray, the Loon River Formation at Hay River, and the Shaftsbury Formation at Zama City. (Darren Tanke and Betsy Nicholls, pers. comm. 2003).

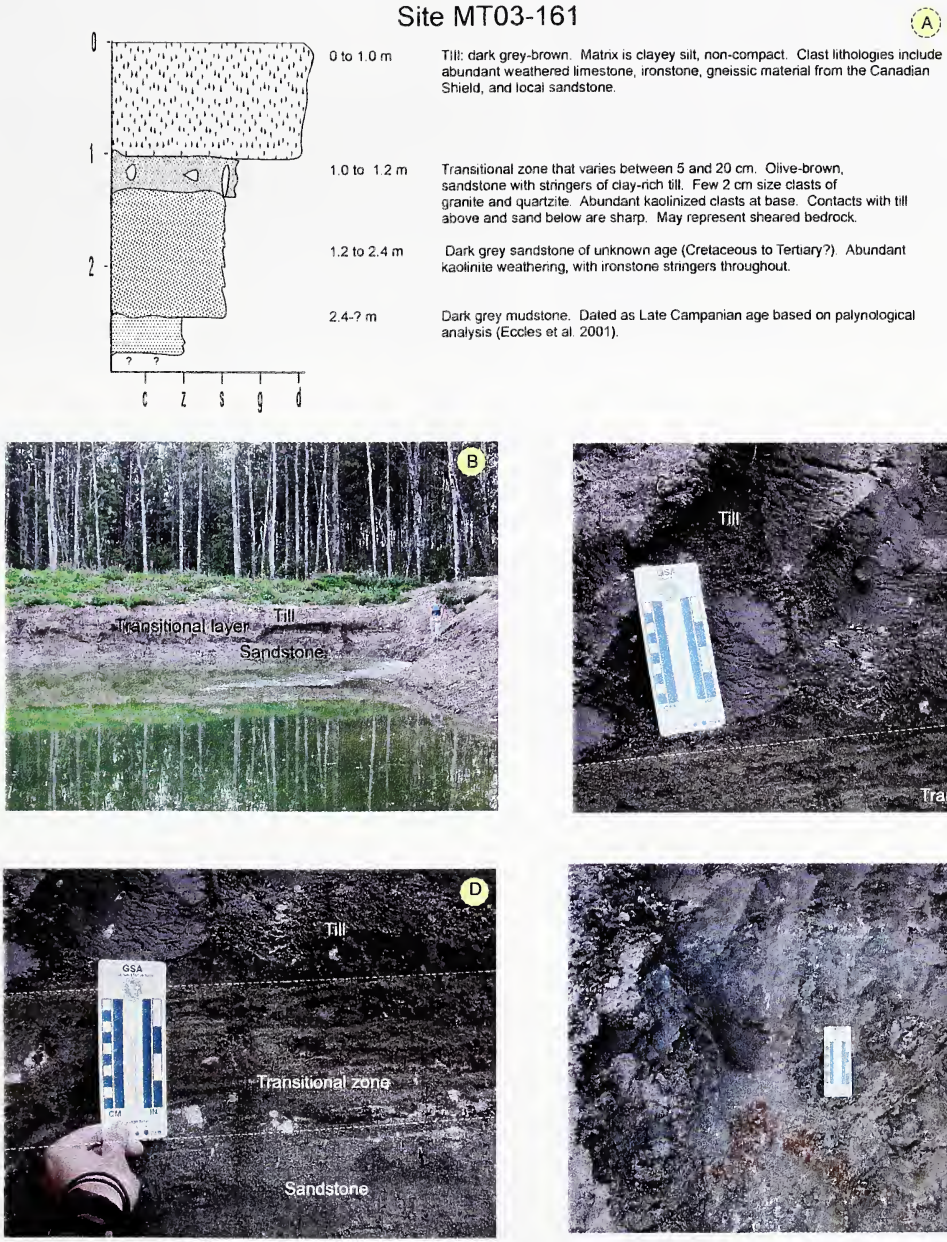
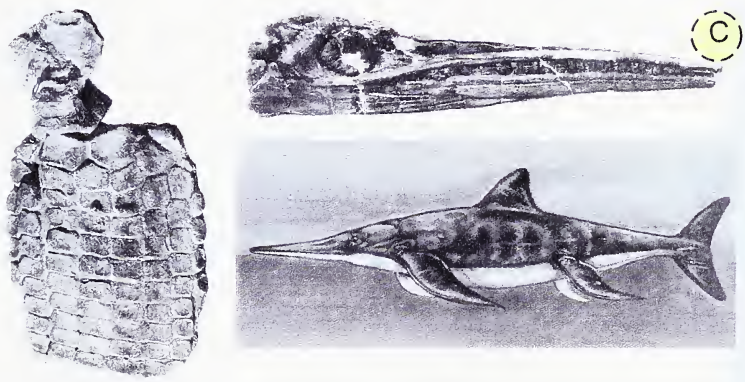

Site MT03-161
A
0
1
2
c z s g d
0 to 1.0 m
Till: dark grey-brown. Matrix is clayey silt, non-compact. Clast lithologies include abundant weathered limestone, ironstone, gneissic material from the Canadian Shield, and local sandstone.
1.0 to 1.2 m
Transitional zone that varies between 5 and 20 cm. Olive-brown, sandstone with stringers of clay-rich till. Few 2 cm size clasts of granite and quartzite. Abundant kaolinized clasts at base. Contacts with till above and sand below are sharp. May represent sheared bedrock.
1.2 to 2.4 m
Dark grey sandstone of unknown age (Cretaceous to Tertiary?). Abundant kaolinite weathering, with ironstone stringers throughout.
2.4-? m
Dark grey mudstone. Dated as Late Campanian age based on palynological analysis (Eccles et al. 2001).
B
Transitional layer
Till
Sandstone
C
Till
Transitional zone
D
Till
GSA
Transitional zone
Sandstone
E

Figure 5. A) Section from recent burrow pit at site MT03-161, recording a till veneer overlying bedrock. B) Site photo showing lithologic units. Person is 5'8." C) Close up of till, showing clayey-silt matrix. D) Transitional zone, showing clay stringers and unit contacts. E) Close view of sandstone. Ironstone stringers are oxidized red and kaolinite is weathered white. The mudstone unit is not seen, as occurs below the water level.



PLATYPTERYGIUS, *the last of the ichthyosaurs, is found in Cretaceous rocks throughout most of the world.* Top right, *the skull of* P. AMERICANUS, *from the Upper Cretaceous of Wyoming.* Left, *an incomplete fin of* P. AUSTRALIS, *from the Upper Cretaceous of Northern Queensland.* Bottom right, *restoration based upon several specimens. The relatively small tail, which contrasts with Jurassic forms, may have been modified for cruising rather than for sprinting. Notice the remarkably long, narrow fins.*

From McGowan 1991

Figure 6. Ichthyosaur fossil found at site MT03-069 entrained in a till hummock. A) Road cut into hummock, on edge of meltwater channel. B) Close-up of fossil teeth and jawbone. Note abundant clasts at surface. C) Sketch of ichthyosaur sent by Besty Nicholls, Royal Tyrell Museum. D) Reconstructed fossil. Reconstruction and identification provided by Darren Tanke, Dinosaur Research Program, Royal Tyrell Museum of Paleontology, Drumheller, Alberta.

Kimberlite emplacement occurred between 86 ± 3 and 88 ± 5 Ma through the Buffalo Head accreted terrane in the Buffalo Head Hills (Eccles *et al.* 2003). Sixteen kimberlite pipes have been discovered within the Sawn Lake map region; kimberlites K5, K6 and K14 crop out. The kimberlitic bedrock is easily weathered, but is substantially harder than the surrounding Cretaceous marine sediments of the Western Canada Sedimentary Basin. Thus, they form positive relief landforms. In addition, each outcrop is associated with a non-vegetated 'kill zone' (Figure 7) due to the toxic geochemistry of weathered kimberlite.

PREGLACIAL GRAVEL

Preglacial gravel has not been previously documented in the Buffalo Head Hills, but were discovered during mapping at sites MT03-003, -004, and -005. These sites occur at elevations of ~800 m, which place them in the highest part of the southern Buffalo Head Hills. The gravels are exposed in a road cut, were dredged up during well site construction and exposed in section at site MT03-005 (Figure 8 A). Site MT03-005 consists of a vertical section cut into a ~ 4 m high hummock during well site construction, and revealed 2 m of till overlying oxidized gravel. The lower till contact with gravel is relatively planar and sharp. There is a small transitional layer with oxidized sand stringers at the base of the till. In addition, the contact contains minor faults that may be the result of ice loading or postglacial rebound (Figure 8 B). The gravel is heavily oxidized, clast-supported (~ 60-70% clasts) with a coarse to medium grained sand matrix with minor massive sand lenses (Figure 8 C). Average clasts have a 4-6 cm diameter, are well-rounded and lithologies include chert / chalcedony, crystalline quartz, quartzite and quartz sandstone, with minor green volcanics and local ironstone

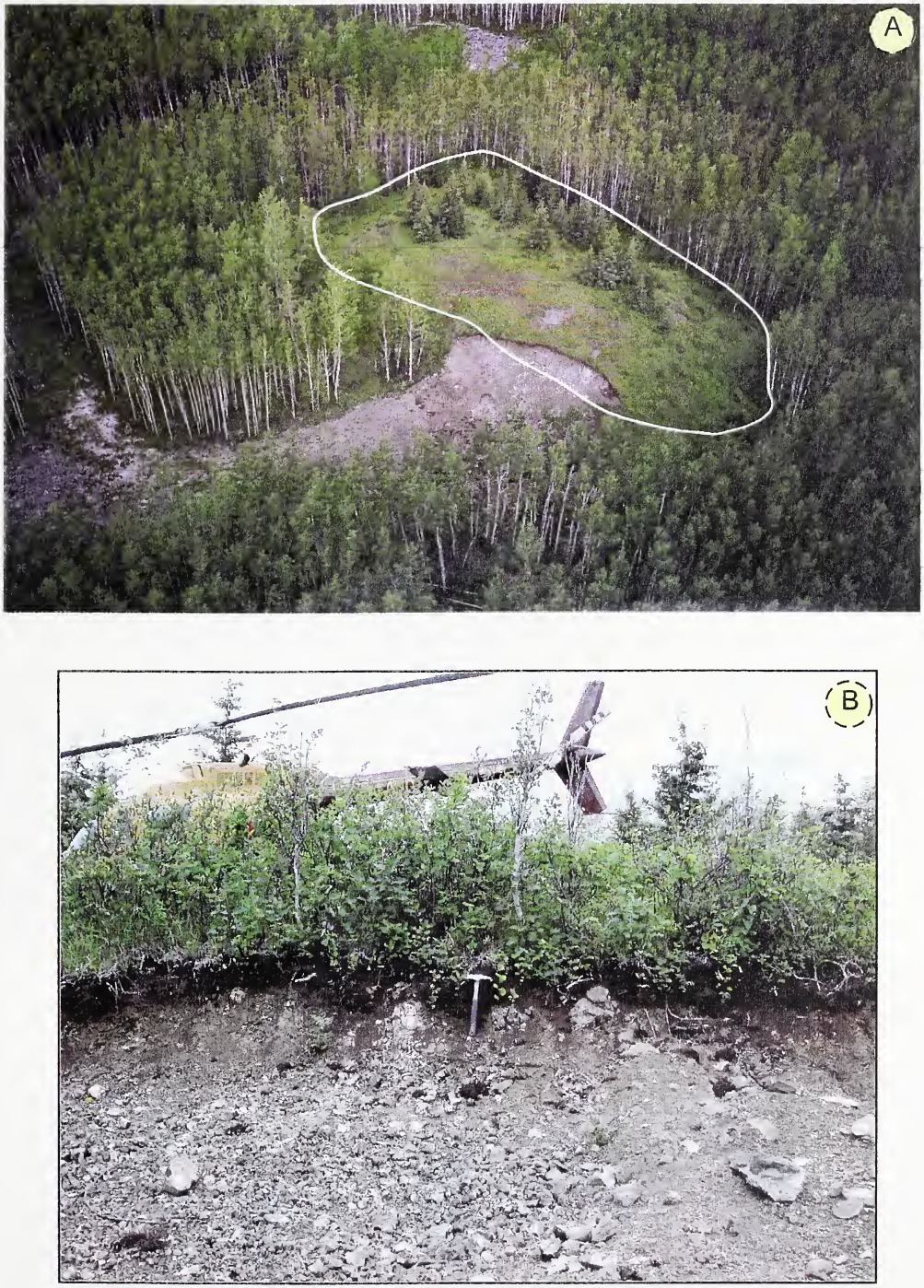


Figure 7. K6 Kimberlite outcrop. A) Natural kill zone (outlined) overlying the kimberlite outcrop. B) Bulldozed outcrop, showing weathered kimberlite at surface with only a small till veneer. Unweathered outcrop near surface exhibits occasional striae.

Figure 8 A. Hummock cut into during well site construction at site MT03-005. 2 m of till unconformably overlying oxidized gravel is exposed. Note gravel spread on well site in foreground.

Figure 8 B. Contact between till and lower oxidized gravel displaying several minor faults which offset the contact.

Figure 8 C. Close-up of heavily oxidized gravel. Well-rounded clasts are supported by a coarse to medium grained sand matrix. There appears to be a slight imbrication direction, though clast analysis was not obtained.

(Table 1, Figure 9, 10). The unit is massive to weakly stratified (horizontal), with slight imbrication of clasts. Note that this site was reclaimed in September 2003 and the gravels are no longer exposed.

Studies by Edward and Scafe (1994) have separated the province of Alberta into six preglacial deposit groups, based on lithology and likely source (Figure 11). Geographically and lithologically, the Sawn lake deposit fits into group 6, which includes the Halverson Ridge, Grimshaw and Watino deposits. At the highest elevation, Halverson Ridge is thought to be the oldest deposit, with Grimshaw recording a lower elevation and possible reworking of the Halverson deposit (Edwards and Scafe, 1994). Watino is stratigraphically the youngest deposit and is radiocarbon dated at 31,530 ± 1400 to >40,170 BP (Liverman *et al.* 1989). On comparison of lithology, the Sawn Lake deposit is most similar to the Halverson Ridge deposit (Figure 12). However, it is lithologically different from all other studied deposits given the high percentage of chert/chalcedony clasts. The lithology of the above-mentioned deposits is significantly different from the lithologies of group 5, which includes the Swan Hills and Pelican Mountain deposits, and likely the groups represent different fluvial drainage systems (Edwards and Scafe 1994).

The age of preglacial gravel deposits in Alberta ranges from early Tertiary (Stalker 1968) to as young as middle Wisconsin (Whitaker and Christiansen 1972; Liverman *et al.* 1989). As the gravel underlies till deposits, the Sawn Lake deposit pre-dates late Wisconsin advance of the Laurentide Ice Sheet (*cf.* Westgate *et al.* 1972; Liverman *et al.*

LITHOLOGIES

mm sieve	Crystalline Quartz	Quartzite	Quartz Sandstone	Black Chert	Green Chert	Red Chert	Ironstone	Green Volcanics
>5.66	297	170	113	240	6	14	13	7
4.76<x>5.66	285	154	69	517	3	15	55	1

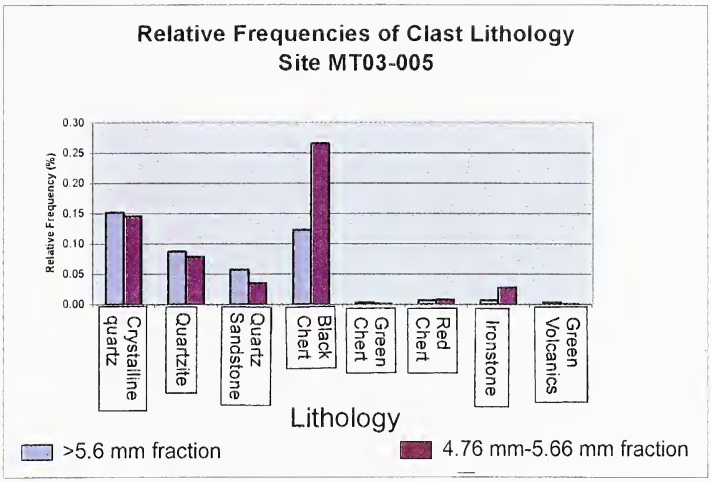
total clasts: 1951

sample was also sieved for the granule fraction, 2.00mm < x > 4.76: not counted, but checked for foreign lithologies.

Relative Frequencies for Lithologies

mm sieve	Crystalline Quartz	Quartzite	Quartz Sandstone	Black Chert	Green Chert	Red Chert	Ironstone	Green Volcanics
>5.66	0.1522	0.0871	0.0579	0.1230	0.0031	0.0072	0.0067	0.0036
4.76<x>5.66	0.1461	0.0789	0.0354	0.2650	0.0015	0.0077	0.0282	0.0005

Above: Table 1 showing clast count completed for lithology of clasts at site MT03-005.
Side: Figure 9 showing a histogram of relative lithologic frequency for each size fraction.



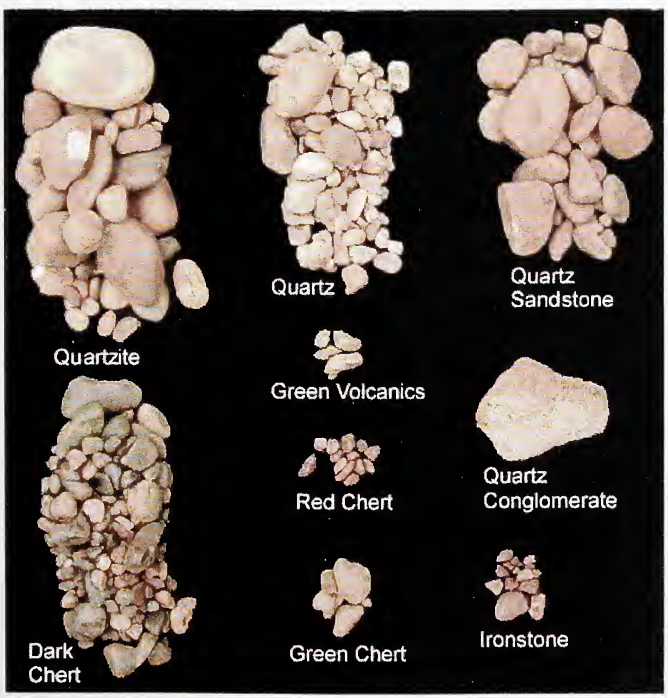


Figure 10. Washed clasts of the >5.66 mm size fraction from site MT03-005. Clasts have been sorted into lithologies. Orange colour is due to intense iron oxidation.

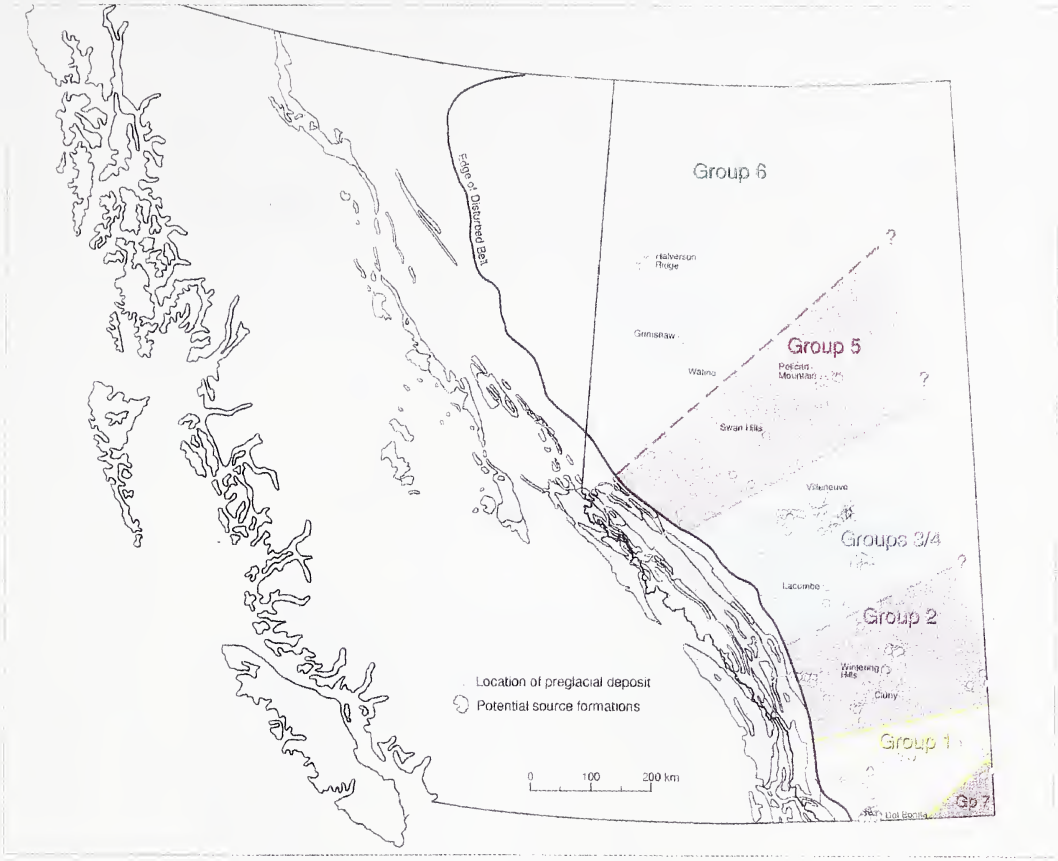


Figure 11. Preglacial deposit (gravel) groups in Alberta, as delineated by Edwards and Scafe (1994). Groups were determined on the basis of streamflow data, elevation, maximum clast size, inclusion of indicator minerals and lithology. In terms of grain size, "Group 5 is predominately coarse gravel, groups 1,2,6 are predominately fine gravel and group 3/4 have a broad grain size distribution." Sand size is similar for all deposits. Lithologically, Group 1 consists of "sandstone, quartzite and argillite." Group 2 is dominately "sandstone, quartzite, carbonate, conglomerate and local sandstone." Group 3/4 is "predominately tan quartzite" while Group 5 is "predominately gray quartzite." Finally, Group 6 consits of "quartzite, quartz, and sandstone."
(From Edwards and Scafe 1994)

Pebble Gravel Comparison for Northern Alberta (percent lithologies)				
	Watino	Grimshaw	Halverson Ridge	Sawn Lake
sandstone	68	28	38	9
quartzite	24	16	26	17
quartz	2	14	25	30
chert/chalcedony	2	12	11	41
metasediment	0	10	0	0
white granite	0	6	0	0
volcanics	0	5	0	present
ironstone (local)	0	0	0	3
conglomerate	4	6	0	present
schist/argillite	0	3	0	0
total	100	100	100	100

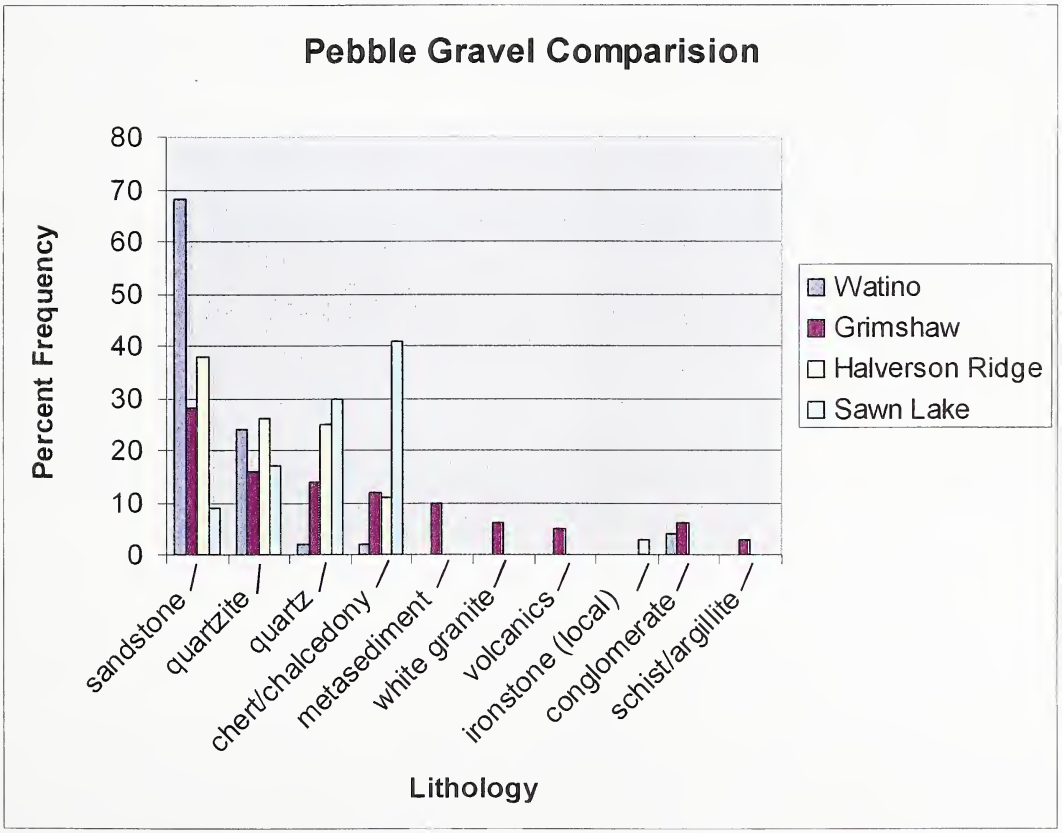


Figure 12. Pebble gravel comparison of site MT03-005 sample with pebble counts from Watino, Grimshaw and Halverson Ridge gravel deposits. All compared deposits are from Edwards and Scafes (1994) group 6. The Sawn Lake deposit is most similar to Halverson Ridge, but differs from all deposits in the high percentage of chert/ chalcedony.

1989). However, the clast relationship to Halverson Ridge (Edwards and Scafe 1994) and the high elevation of the deposit suggests that the Sawn Lake deposit is likely early Pleistocene gravel in the Buffalo Head Hills.

SURFICIAL GEOLOGY

The present day landscape of the Sawn Lake region is a result of preglacial fluvial incision and later multiple glacial and nonglacial events. Surficial sediments predominately reflect advance and retreat of the Laurentide Ice Sheet during the last (Late Wisconsin) glaciation (Dyke *et al.* 2002) and subsequent Holocene fluvial erosion and bog development.

Surficial materials are classified according to sedimentology including texture (grain size), sorting and sedimentary structures in combination with associated landforms and interpreted genesis when possible.

Texture

Texture is inherent in the description of the unit and textural symbols are used only where the texture differs from expected.

c – Clay: particles < 4um

$ - Silt: particles 62.5 < x > 4 um

s – Sand: particles 2 mm < x > 62.5 um

g – Gravel: > 2mm, pertaining to pebbles, cobbles and boulders; usually a mixture of above components comprising the matrix with gravel-size clasts

This differentiation according to texture is an important aid in identifying glaciofluvial areas containing gravel in addition to sand.

Landforms

c Crevasse fill: ice-contact ridges and linear forms deposited by meltwaters in stagnant ice; or ice-contact ridges formed by squeezing of basal till into crevasses. Genetic interpretation relies on sedimentology and morphostratigraphy.

d Doughnuts: circular ridges with a depression (often containing organics) in the center, plateau mounds

e Eroded: planar surface eroded by glacial meltwater, often capped by a thin veneer of glaciofluvial deposits

h Hummock: terrain consisting of approximately equideminsional hills and depressions with moderately high relief (> 2 m)

p Plain: relatively flat-lying deposits often masking topography of underlying sediments and with a thickness greater than 2m

r- Ridge- one or more parallel or sub-parallel, convex, linear morphologic elements with a width to length ratio greater than 2 m, relief <1m to several metres

s- Slumped- landslide blocks, slope failure debris

t- Terrace- terrace bench cut by either meltwater or Holocene fluvial erosion

u Undulating: low-relief (<2m) rolling terrain

v Veneer: a thin mantle of unconsolidated material ranging in thickness from 10cm to 2m

y Dissected: surfaces channeled by glaciofluvial meltwater or Holocene fluvial activity

Ice advance glaciofluvial gravel

Ice advance sediments do not occur on the surface, but were intersected by drill holes, a single road cut and backhoe trenching in the region near K4 kimberlite (Paulen *et al.* 2003d). The deposits consist of massive medium-grained sand and bedded sand with moderately sorted gravel beds, and include lithologies derived from the Canadian Shield. These sediments are interpreted as ice-advance outwash deposited proximal to the advancing ice margin during the late Wisconsin advance of the Laurentide Ice Sheet, and are also seen at the community gravel pit in Red Earth.

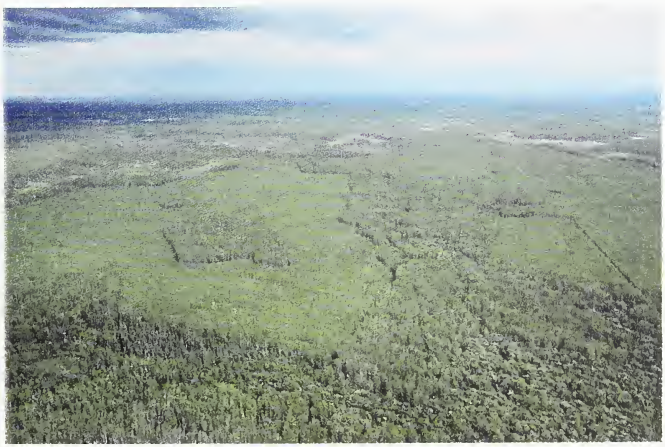
Till/Moraine

Surficial tills in the region are the product of the late Wisconsin Lostwood Glaciation (Fenton 1984) associated with the advance of ice during the last glaciation (marine isotope stage 2). Till, or ground moraine, occurs at the surface on the margins of the Buffalo Head Hills and in the Wabasca Lowland. The till is characterized by diamicton with a silty-clay to clayey-silt matrix, commonly fissile and compact, averaging 1-5% clast content (Figure 13A). Typically, a Luvisolic soil profile is developed on the till, representative of Holocene soil development (Soil Classification Working Group 1998). This profile includes 10cm leaf litter horizon, 10cm Ae horizon, 50cm B horizon (no limestone), and a 50cm C horizon (enriched in carbonate). In addition, the profile is typically brown at surface, with a gradual colour change to grey at about 4m depth (Figure 13 B). Thickness of till ranges from thin veneers (<2 m) to in excess of 10 m in the map area (Pawlowicz and Fenton 2004b). Topographically, the deposits form flat,

Figure 13 A. Representative sample of clay-rich, partially oxidized till from site MT03-112.

Figure 13 B. Burrow pits at site MT03-112, exposing soil profile and till.

Figure 13 C. Helicopter photo showing clear-cut logging of deciduous vegetation on a till plain in the southeastern map area.



low-relief to slightly undulating plains (Figure 13 B, C). It is considered basal or lodgement till, deposited directly by glacial ice without transport or modification by subsequent processes (Dreimanis 1989).

Clasts are typically faceted and striated, ranging in size from pebble to boulder, with an average of 1-2 cm diameter. Lithologies include quartzite sandstone, ironstone (siderite), local bedrock (shale, sandstone, mudstone, coal), limestone (commonly fossiliferous), reworked preglacial quartzite and black chert, and metamorphic and igneous rocks (granite, gneiss, metavolcanics) derived from the Canadian Shield (Figure 14). Clasts such as ironstone, limestone, granites and gneiss are often strongly weathered in the upper soil profile. Clast provenance is derived from outcrops in northern Saskatchewan (Athabasca Basin), platformal Paleozoic limestone rocks of northeastern Alberta and the Northwest Territories, Canadian Shield derivatives from north Saskatchewan and the Territories (metamorphic and igneous). Cordilleran gravel deposits (quartzite and chert) sourced from the Rocky Mountains to the west and locally reworked in the till, and local ironstone, shale, mudstone, coal and sandstone from the underlying bedrock.

Aerial photographic identification, in combination with ground truthing stations, allows till polygons to be delimited. This is aided by identification of low relief regions in association with deciduous or healthy mixed forest (i.e. poplar and white spruce) (Figure 15). Due to silty clay texture and low gradient, water tables are often perched and the moraine plains host numerous Holocene fens and peat bogs, seen predominately in the eastern region of the Sawn Lake map area.

Figure 14. Representative photo of clasts weathering out of a till hummock at site MT03-169. Note abundant limestone, granite, gneiss, Athabasca sandstone, chert, quartzite and ironstone. Appearance of high clast content is due to slope wash.

Figure 15. Representative stereopair showing flat-lying till plain in the southern map area. Meltwater channels are delineated on the left photo. (Aerial photographs 89-145 Line 31 AS940-284,-285, 1:20 000, Alberta Sustainable Resource Development).

Dominant on the uplands of the Buffalo Head Hills is a different type of till, characterized by diamicton with a matrix ranging from sandy-silt to silty-clay. The matrix is typically poorly compacted and local sand lenses (2-5 cm thick, medium to coarse grained) are common. The diamicton contains 5-10% clasts, which are more angular and less polished than the faceted clasts of basal till, though of the same lithology. The moraine may be weakly stratified, likely due to the greater presence of water during its formation. Topographically, the moraine is typified by undulating to hummocky terrain consisting of roughly equideminsional hills and depressions (Figure 16 A, B). Relief is often greater than two metres, though is variable throughout the region, which creates a landscape significantly different from basal moraine. This till is thought to represent glacial sedimentation during ice stagnation and retreat, and is called stagnant ice moraine; referring to a combination of melt-out till, glaciofluvial and glaciolacustrine material (Dreimanis 1989, Boulton 1976)

Aerial photographic identification, in combination with ground truthing stations, allows for recognition of stagnant ice moraine polygons. This is accomplished by identification of undulating to hummocky topography in combination with deciduous or healthy mixed forest vegetation associations indicating a well-drained substrate (Figure 16 C).

The stagnant ice moraine often forms doughnuts consisting of a roughly circular till hill and a centre depression in-filled with lacustrine sediments and subsequent bog peat. During fieldwork, a probe-transect was completed at site MT03-176, with a 320° trend over a typical doughnut shape (Figure 17 A, also seen in the lower part of Figure 22). A cross-section was obtained (Figure 17 B), recording both lithological and vegetational

Figure 16 A. Hummocky stagnant ice terrain near Sawn Lake.

Figure 16 B. Part of hummock seen as a road-cut at site MT03-042

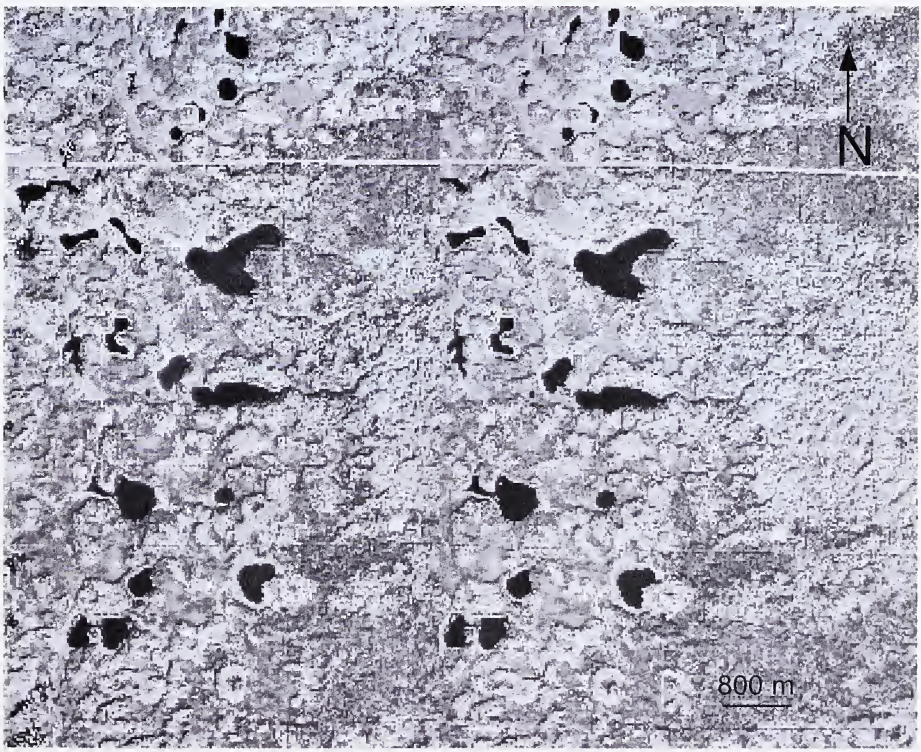


Figure 16 C. Representative stereopair showing hummocky stagnant ice moraine with occasional doughnut forms. Aerial photographs 00-109 Line 91 AS5121-136,-137, 1:40 000, Alberta Sustainable Resource Development)

Figure 17 A. Stagnant ice hummock (doughnut) at site MT03-176. Line indicates 250 m probe transect completed.

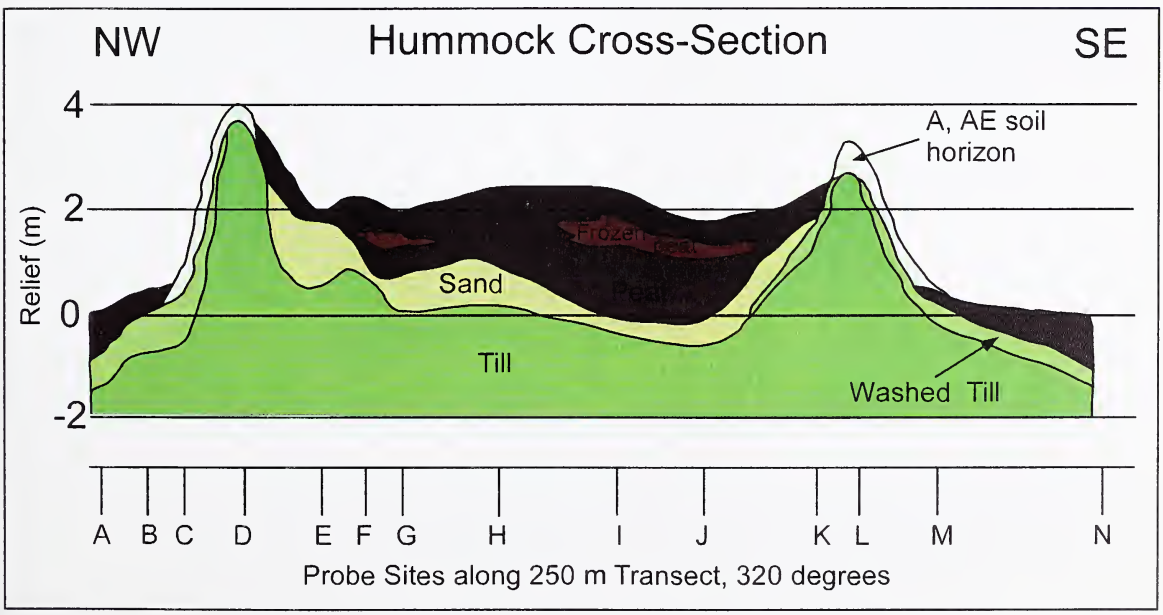


Figure 17 B. Cross section of figure 16 A at site MT03-176. Note till rims and organic centre fill.

changes over a total distance of only 250 m (Table 2, Figure 18, see appendix A for full site description).

Crevasse Fill

Crevasse fills are mapped in the southwest region of the map area, occurring within till plains veneered by organics. Field studies on lithology and stratigraphy of these features are required before an interpretation can be confidently applied. None of these features were accessible in the field and were identified on aerial photographs, aided by linear ridge geomorphology in association with well-drained deciduous vegetation (Figure 19).

Site	Subsurface lithology	Surface Vegetation
A	frozen and unfrozen organics over slope wash	stunted black spruce, sphagnum
B	organics, mineral soil, grades to till with minor sand lenses	6-7 m high black spruce, thicker vegetation
C	sphagnum, weathered soil, slope wash/ silty clay	open forest floor with large pine and spruce
D	organics, weathered profile, dense till	deciduous forest (poplar, aspen)
E	organics, rhythmically bedded silt/clay, massive silt and fine sand	willow, white spruce, black spruce
F	unfrozen and frozen peat, woody	tall white spruce forest, minor moss
G	unfrozen and frozen peat, woody	stunted spruce and abundant peat/moss hummocks
H	unfrozen peat, woody layers, mixes with silt layers at depth	stunted spruce and abundant peat/hummocks
I	unfrozen peat/moss, frozen peat, woody and fibrous peat at depth	stunted spruce and abundant sphagnum
J	unfrozen and frozen peat, layered and woody at depth	stunted spruce and abundant sphagnum
K	unfrozen and frozen peat, sandy grit at base	stunted spruce, sphagnum
L	weathered profile, dense and compact till	open forest floor, large poplar/aspen
M	weathered profile, sand and silt	open forest floor, large poplar/aspen
N	organics over slope wash and till	stunted black spruce, sphagnum

Table 2- Probe and surface data obtained during transect at site MT03-176.

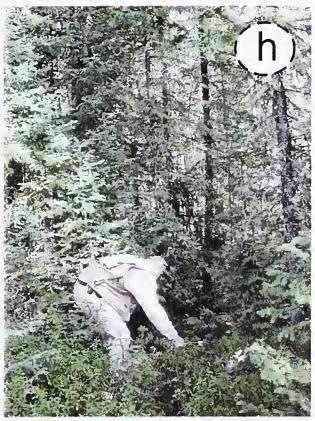


Figure 18. Vegetation and probe contents at representative sites during probe transect of site MT03-176. A) Forest at site A. B) Frozen peat in probe, site A. C) Site C at base of slope. D) Upper soil profile in probe at site D E) Forest at site F. F) Site G, peat hummock in foreground, pine rim in background. G) Frozen layered peat in probe, site J. H) Forest at site K. I) Forest at site L.

Glaciofluvial sediments

Valley systems are found throughout the map area, extending up to 20 km in length, and exhibiting depths up to 50 m. The channels represent the most prominent topographic features in the map area, being of significantly greater negative relief than the positive relief depositional forms (i.e. moraine, bedrock) (Figure 20). This pronounced negative relief was formed while ice was still in the region.

Tunnel Channels

As water occupies separate ponds within some meltwater channels, a topographic high can be interpreted between ponding, seen in Figure 21 and within many of the mapped meltwater channels. Field checking is required to confirm this hypothesis, as normal scouring within channels can also create an undulating channel base. These channels incise the moraine deposits, contain under-fit modern lakes and rivers and are presently in-filled by modern Holocene organic and alluvial sediments. Glaciofluvial sedimentation is mainly confined to the channel, with deposits of well-sorted, massive to bedded, coarse to fine grained sand. If a convex-up profile does exist within these channels, they may be interpreted as sub-glacial meltwater channels, rather than proglacial topography-driven channels (Rains *et al.* 2002).

Proglacial Channels

Some incisions are interpreted as ice-marginal and proglacial meltwater channels. The ice-marginal channels tend to flow along topography rather than down gradient, defining retreating ice margins. In the Sawn Lake map area, these channels are oriented roughly

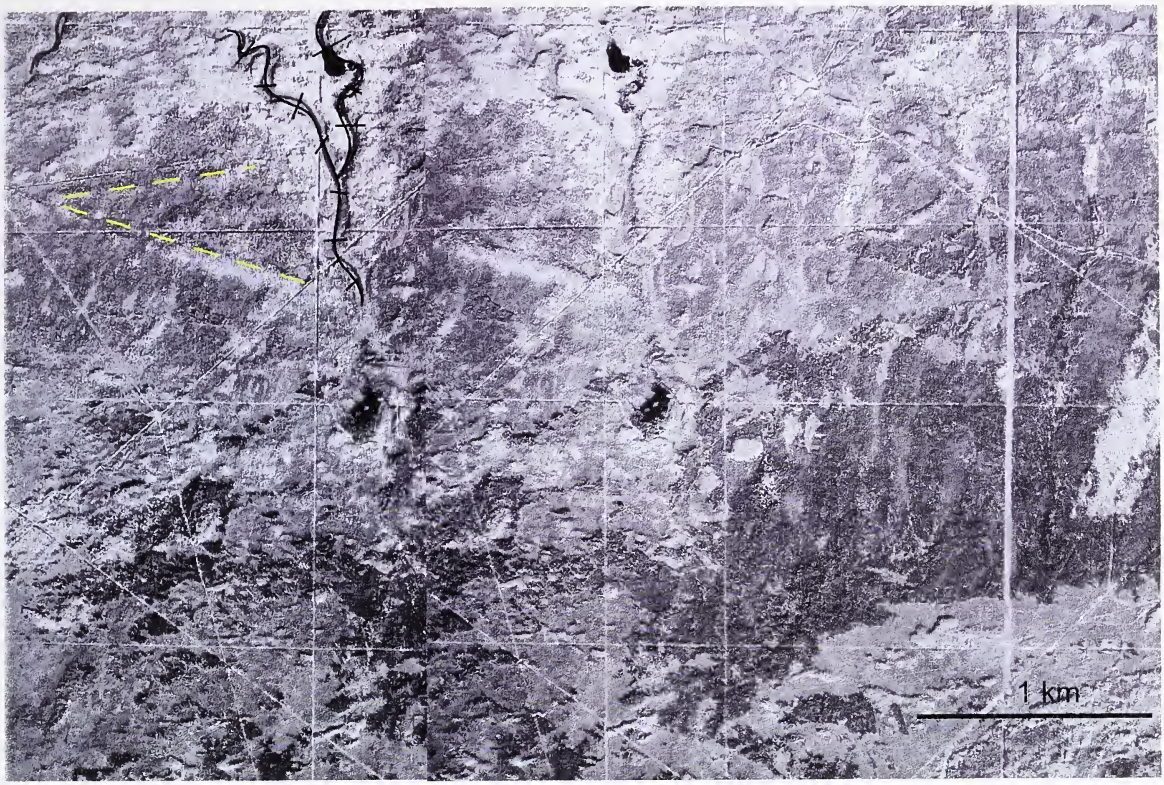


Figure 19. Representative stereopair delimiting crevasse fill in yellow and a meltwater channel in black. (Aerial photograph 89-145 Line 33 AS-3940-273,-274, 1: 20 000, Alberta Sustainable Resource Development)

Figure 20. Site MT03-034 on edge of a meltwater channel. View is to the northeast. Truck for scale, shows the depth of channel in comparison to surrounding topography.

Figure 21. Ponding within a meltwater channel west of site MT03-051. The two ponds separated by a topographic high suggest a convex-up channel base.

NNW and can be found on the uplands and southern flanks of the Buffalo Head Hills. In contrast, proglacial channels flow across topographic gradients and are associated with sorted glaciofluvial outwash deposits. They are found predominately along the flanks of the upland. In the southwest map area, these north-south oriented channels contain under fit modern streams and cross-cut wider NNW to east-west trending channel forms. Thus there have been at least 2 main episodes of glaciofluvial deposition during retreat, both ice-marginal and later proglacial; though it is also possible that at least one episode is subglacial, defining a large subglacial drainage tract.

The proglacial channels may also exhibit more sinuous meandering profiles, as seen by the large-scale meanders of Haig lake in NTS sheet 84C/16, which join up with the meltwater channels leading south from Sawn Lake (Figure 22) and by small-scale meanders throughout the map area (Figure 19). It is thought that the Haig Lake channel is not a tunnel channel, given presence of meander bends, probable terraces and association with outwash deposits on channel margins. It is possible that this meltwater channel represents a reoccupying of a preglacial river valley, which would account for the large-scale meanders. Detailed bedrock topography is necessary to support this hypothesis.

Glaciofluvial Plain

Portions of the Sawn Lake region are dominated by late-glacial meltwater sedimentation, recorded by the presence of outwash plains in the central and southwestern map region.

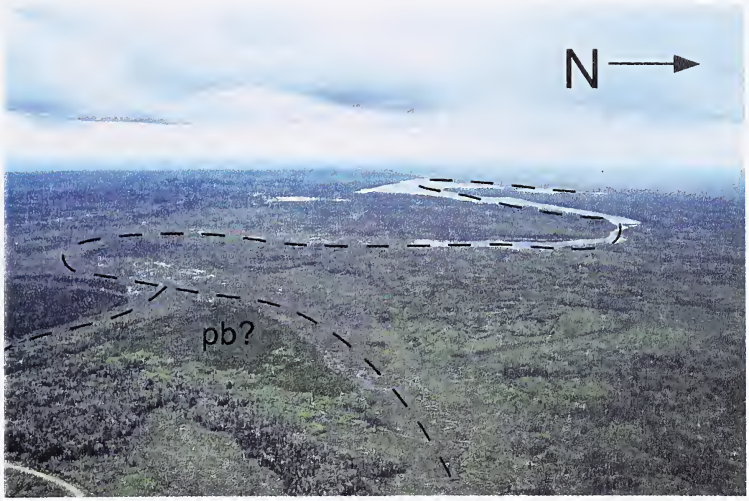


Figure 22. View of Haig lake, NTS 84C/16. Meanders possess an amplitude of up to of 3.5 km, and are likely a result of proglacial outwash channels, though may have initially been preglacial. pb? indicates possible point / lateral bar formation within the channel. Meanders join with channels draining from Sawn Lake to the east and are occupied by the Little Cadotte River.

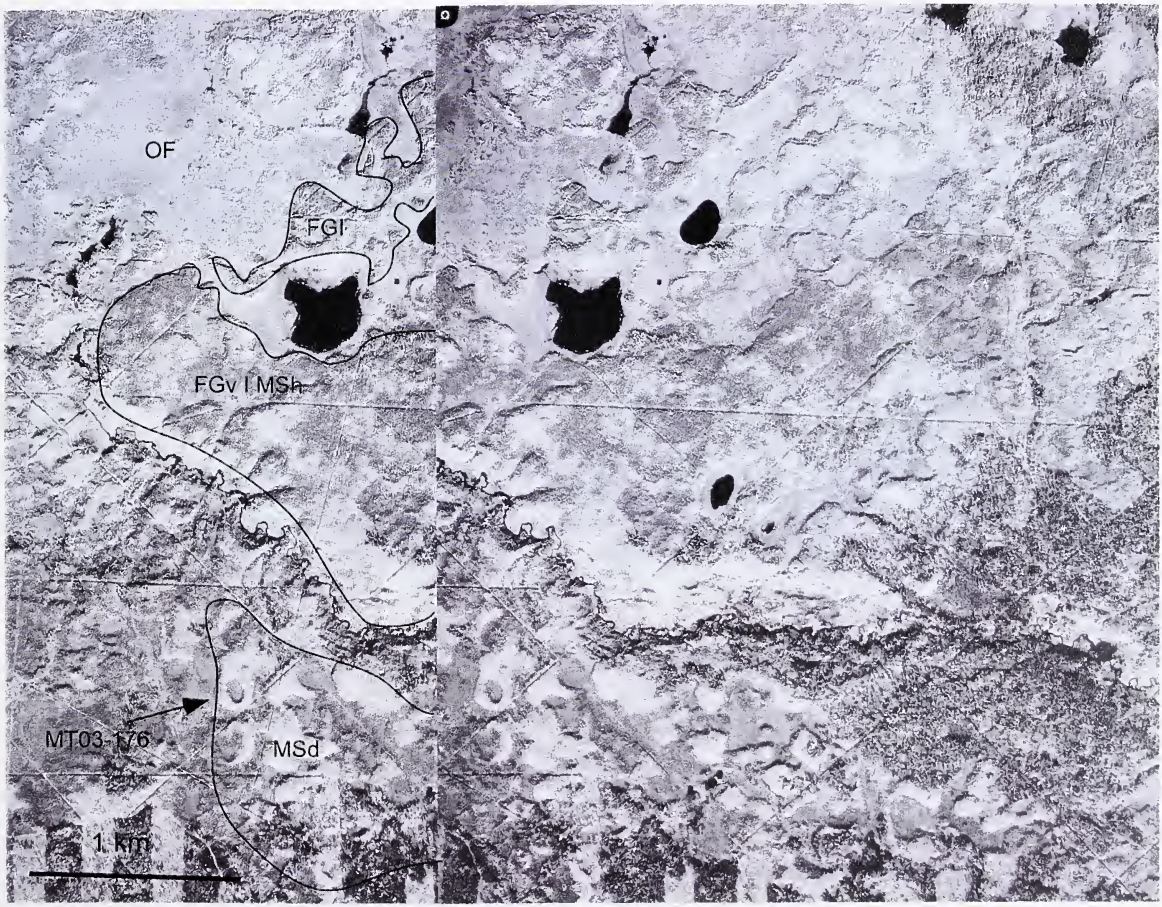


Figure 23. Representative stereopair delimiting regions of glaciofluvial outwash, fen deposition and a region of stagnant ice moraine. Note arrow points to doughnut studied at site MT03-176. (Aerial photographs 89-185 Line 32 AS-3941-66,-67, 1: 20 000, Alberta Sustainable Resource Development)

These sediments define broad proglacial outwash channels/plains and are commonly overlain by organics.

Aerial photographic interpretation, in combination with ground truthing stations, allows glaciofluvial polygons to be delimited. This is aided by identification of low relief regions (with the exception of ice-contact sediments) in association with a more open, well-drained forest floor, reindeer lichen, pine and deciduous flora (Figure 23).

The central region of outwash includes both glaciofluvial sand as well as gravel; geomorphologically ranging from flat-lying to hummock and ridge deposits (Figure 24 A). These deposits appear rather sharply in the north, and are absent south of the modern river valley. There is no local source for the coarse gravel or relationship to topography (i.e. confined depression) and this region may represent an area of subglacial deposition. Subglacial pressing/ice contact of the soft-sediments would account for the undulating to hummocky topography of these sediments; unexpected within outwash plains unless draping hummocky terrain. If overlying hummocky terrain, this implies that the glaciofluvial deposits are a result of supraglacial sediment release/flow during stagnation and melt. Site MT03-105 on the outskirts of this deposit does preserve sand overlying till, though the till is flat-lying. Given the clast-poor nature of the till and topographic considerations, the thickness and probability of such a draping deposit is uncertain for this region.

Ice Contact Glaciofluvial Sediments

Ice-contact sediment occurs in the form of small 0.5 km diameter kames, eskers averaging 1 km along strike, and possibly small crevasse fill deposits. These ice-contact deposits consist of poorly sorted, massive to crudely stratified gravel, sand and minor silt.

The esker at site MT03-096 is seen by a road-cut cross-section (Figure 24 B). It consists of predominately massive sand, with minor interspersed gravel. The large esker just to the south is the site of an active gravel pit. Recent excavation has exposed planar cross-bedding within sand, with interstratified gravel (Figure 24 C, D). The clasts average 10cm diameter, and include kimberlite cobbles from the nearby K4 kimberlite.

Glaciolacustrine sediments

Glaciolacustrine sediments are rare in the Sawn Lake region, given the Buffalo Head Hills topography, but can be found in the nearby Loon River lowlands (Paulen *et al.* 2003a; 2003b) where they extend over 10 km by 10-20 km (depending on their presence under large, poorly drained, organic plains); due to retreating ice blockage of meltwater drainage down the Wabasca River. Typically, glaciolacustrine sediment is fine-grained, well-sorted, massive to laminated/rhythmically bedded silt and clay with minor sand. Washed till lags and littoral sand mark the former shorelines of larger glacial lakes, seen in the map area near Sawn Lake. Washed till surfaces were also found on the eastern border of the map area, possibly associated with nearby glaciolacustrine plains in the lowlands.

Figure 24. Characteristics of glaciofluvial ridge deposits. A) Sand and gravel ridge at site MT03-142, part of a large glaciofluvial deposit with flat-lying to hummock and ridge topography. B) Road-cut profile of sand-dominated esker at site MT03-096. C) Excavated section of esker used as an aggregate resource. D) Close view of esker stratigraphy showing cross-bedding with gravel lag near top.

Local ponding has occurred within the stagnant ice-terrain, both surrounding the hummocks, and within the doughnut holes of stagnant ice moraine hummocks. Mapping of glaciolacustrine sediment in this terrain is difficult given the thin (< 2 m) nature of the deposits and draping of organics in the lowlands. Thus, their occurrence may be underestimated in the map-area.

Ice Contact Glaciolacustrine Sediments

Flat-topped, relatively steep-walled hummocks of 20 m diameter and 3 m relief occur in the southwestern portion of the map area, documented at site MT03-149 (Figure 25 A, B) and surrounding area. These are roughly circular to ovate geomorphic features, consisting of horizontally bedded, well-sorted rhythmites of clay, silt and fine-grained sand; finely laminated with bed thicknesses between 1 and 8 cm. The origin of these features is unclear, but they may represent supraglacial ice-walled lakes; formed during periods of stability when they melted down to the solid moraine base (Clayton and Cherry, 1967; Ham and Attig 1996). During later periods of instability, rapid melting caused drainage of the lakes and preservation of a raised plateau. It is also possible that the forms represent erosional remnants created during subglacial or proglacial meltwater flow and are not stagnation features.

Colluvium

Colluvium is dominated by a moraine sediment source, but also includes bedrock, glaciofluvial, glaciolacustrine and Holocene sediments. Sediments are defined as colluvium once displaced due to gravity and record various slump and flow processes;

Figure 25 A. Photo of suspect ice-walled lake deposit at site MT03-149. Picture is taken at forest floor level and shows 3 m relief of ovate geomorphic feature. The feature is well drained and exhibits deciduous flora relative to the poorly drained forest floor bog deposits .

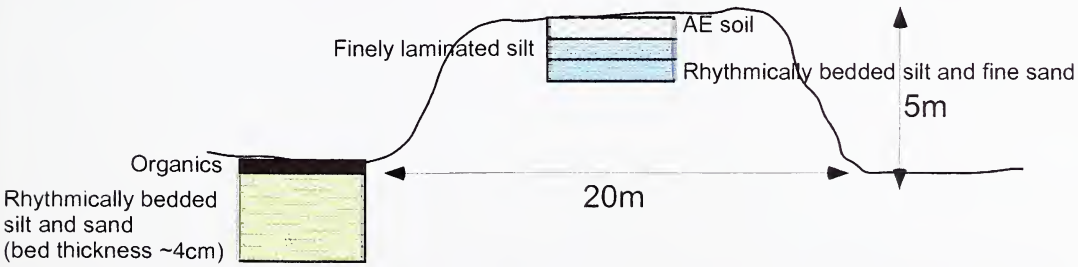


Figure 25 B. Schematic section of stratigraphy and geomorphology found at site MT03-149. Both lithologs were taken from probe data, at the top of the feature, and on the forest (bog) floor. Surrounding lithology of forest/bog floor is interpreted to be sediment found within a meltwater channel or outwash plain, overlain by organics due to poor drainage.

found along unstable, steeply incised channels (Pleistocene or Holocene). Sediments are poor to non-sorted, unconsolidated and consist of a variety of grain sizes. Colluvium was mapped based on aerial photographs and topographic contours, occurring on the steep slopes of the larger glaciofluvial/fluvial channels.

Fluvial (alluvial)

Modern drainage in the Sawn Lake region is poorly developed due to the low topographic gradient and the impermeable nature of moraine and glaciolacustrine sediments. As a result, small streams of varying orientation occur. Commonly, modern drainage occurs as under-fit streams occupying large glacial meltwater channels. In addition, beavers are common in the region, blocking streams, often in succession. This has caused substantial erosion and diversion of surface drainage leading to standing water (bogs) and fens. Modern fluvial sediment is dominantly fine-grained with organic detritus and minor gravel and sand in more developed streams.

Organics

Due to low slope gradients and low permeability of surface sediments, organic deposits are found throughout the map region in areas of poor surface drainage such as moraine plains and in depressions surrounding stagnant ice moraine. They occur as wetlands such as fens and bogs, recording a transition from the former to the latter with maturity (Figure 26). Fens represent alkaline, nutrient-rich peatlands, dominated by sedges, willow and tamarack trees (Figure 27). In addition, fens are likely to exhibit water ponding due to surface recharge. In terms of aerial photographic interpretation, fens are represented as

Figure 26. Kettle lake maturing from a fen to a bog.

Figure 27. Modern fen occupying an old glacial meltwater channel in the southwestern map area.

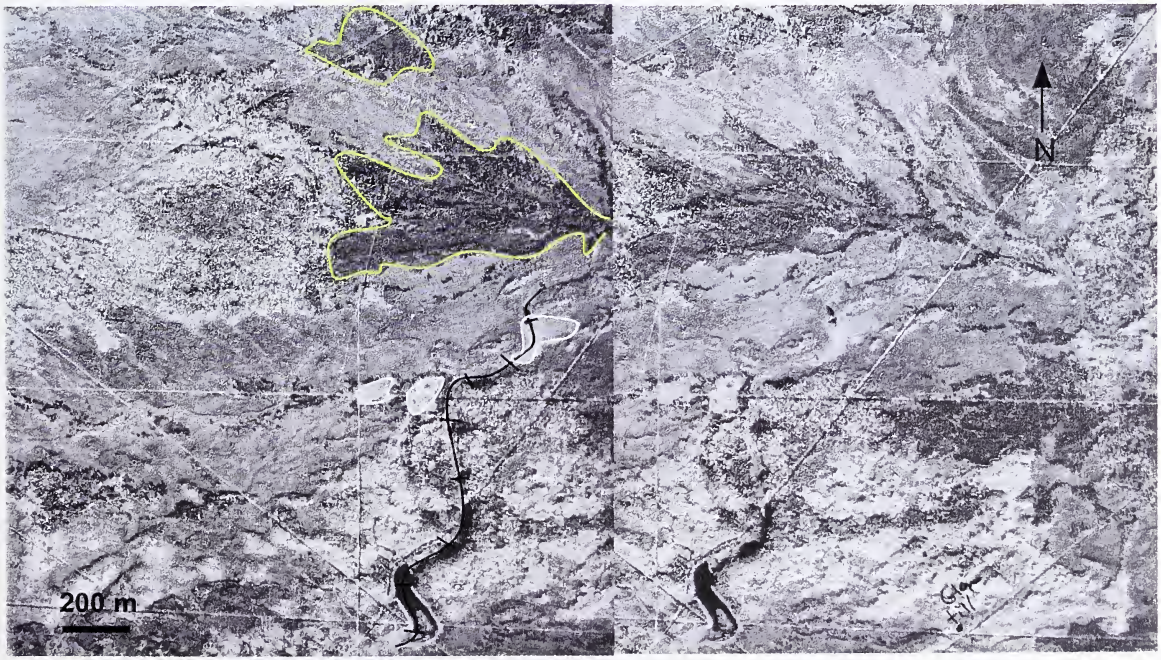


Figure 28. Stereopair outlining fens in white, raised spruce bogs in yellow and a meltwater channel. (Aerial photographs 89-185 Line 32 .AS-3941-61,-62, 1:20 000, Alberta Sustainable Resource Development).

highly reflective (white) lowlands (Figure 28) In contrast, bogs represent acidic, nutrient deficient raised peatlands (Figure 29 A). Sphagnum mosses (Figure 29 B), reindeer lichen (Figure 29 C), bog birch and stunted black spruce trees are the dominant bog vegetation. Bogs are less likely to exhibit surface water, but tend to occur in regions of fluctuating water table maintained by precipitation. Aerial photographic identification of bogs is aided by low reflectance (black) raised surfaces, generally within lowlands and commonly showing drainage patterns (Figure 28). In areas of significant peat thickness, the peat is often frozen and may represent local areas of discontinuous permafrost (Figure 29D). In addition, the peat often overlies a thin (<20cm) fine-grained sediment horizon (Figure 29 E).

Occurrences of organics in the southwest portion of the map area appear to infill the topography of low areas, in particular occupying areas of former meltwater channels/outwash plains and glaciolacustrine sediment. Indeed, there are many areas within the map region where organic deposits take on long, linear shapes and are more likely related to glacial channels, than to simple ponding and lack of drainage (Figure 30)

GLACIAL HISTORY

Ice Flow History

The Laurentide Ice Sheet advanced from the northeast into the Sawn Lake Map region. According to regional studies, ice advanced to its maximum Late Wisconsin (marine isotope stage 2) limit approximately 23-24 ka BP (Dyke *et al.* 2002) within the region. Geomorphic ice flow data is not easily obtained in the map area, due to its location within

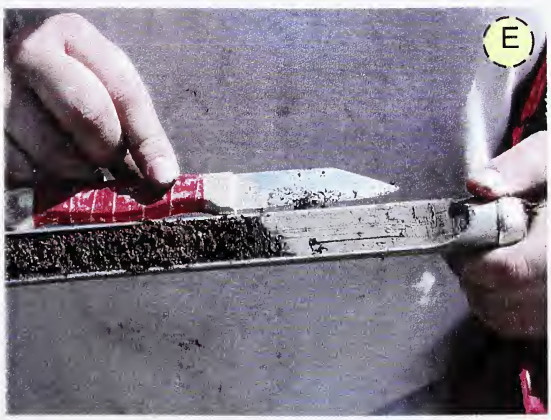


Figure 29. Characteristics of bog deposits. A) Stunted black spruce, sphagnum and moss visible along a seismic line. B) Various mosses and lichens found associated with peat hummocks C) Reindeer lichen associated with well-drained areas. D) Probe length containing frozen peat. Note ice crystal where finger is. E) Contact within probe of peat overlying fine-grained mineral soil.

the poorly indurated bedrock of the Western Canada Sedimentary Basin. However, presence of kimberlite pipe outcrops provide an interpretation of advance direction to substantiate regional flow data. The strongly sculpted crag and tail feature at K5 kimberlite exhibits a south-southwest azimuth, which supports a regional flow advance from the northeast (Figure 31). Striae are especially unusual in the region, but rare striae have been documented on the K6 kimberlite outcrop with an azimuth of 215.° Regions to the north of the map area have not yet been mapped at any scale and further mapping is required to establish detailed local and regional ice flow reconstruction.

Till fabrics completed during fieldwork in 2001 and 2002 allude to complexities in ice-flow history not seen from simple aerial photograph interpretation (Paulen *et al.* 2003e) (Figure 32). Pebble fabrics measured in tills indicate that during the early stages of deglaciation, an ice lobe advanced from the Peace River Valley and flowed southeasterly over the southwestern flank of the Buffalo Head Hills. This flow was then deflected by ice flowing south-southwest through the Loon River Valley, as indicated by striae trending ~188° on a boulder pavement at the Red Earth airport and corresponding flutes in the Wabasca River lowland (Paulen *et al.* 2002). During deglaciation, the ice sheet stagnated on the Buffalo Head Hills upland, while continued advancing in the lowland to the east (Paulen *et al.* 2003e). Eskers are rare, and generally occur in the stagnant ice terrain, making them a poor indicator for deglacial ice flow trends.

Figure 30. Modern organics/fluvial sediment within glacial meltwater channel draining from Sawn Lake in the northwest map area.

Figure 31. Sculpted crag and tail feature, created by ice advance over K5 kimberlite pipe outcrop. Ice flow is from left to right (SSW) with helicopter view from north.

Stratigraphy

Uncertainty exists regarding the behaviour of the Laurentide ice-sheet during advance into the Canadian prairies. Fenton (1984) identified four Laurentide glaciations, though the extent of these glaciations in Alberta is poorly understood (Liverman *et al.* 1989, Young *et al.* 1994). The glacial history of the Buffalo Head Hills is complex, and at least two stages of glaciation are recorded (Figure 33, Fenton *et al.* 2003b). A non-calcareous lower till observed during drilling exhibits oxidized (Borehole 11, Appendix B) and paleo weathering profiles (Borehole 8, Appendix B), overlain by glaciolacustrine sediments in addition to glaciofluvial sands and gravels; capped by an upper calcareous till. It is proposed that the lower till is early Wisconsin age (or older?), belonging to the Burke Lake Glaciation (Fenton 1984) while the upper till is late Wisconsin of the Lostwood Glaciation (Fenton 1984). Interstadial and interglacial ages obtained from northern Alberta are rare, but a mid-Wisconsinian (wood) date has been obtained from the Birch Mountain Hills between two tills (Roger Paulen and Alwynne Beaudoin; pers. comm. 2004) 140 km to the northeast of the map area. To the south, Saint-Onge (1972) cites a C14 radiocarbon date of 52, 200 ± 1760 for material between two tills at his Freeman River Section. It is also plausible that the tills represent local advances and retreats of the same late Wisconsin glacial event, though the till geochemistry is substantially different (Fenton *et al.* 2004). Further work involving radiocarbon dating is needed to constrain the possible presence of the 'ice-free corridor' and/or the extent of pre-late Wisconsin glaciations within Alberta (Rutter 1984, Liverman *et al.* 1989, Burns 1996).

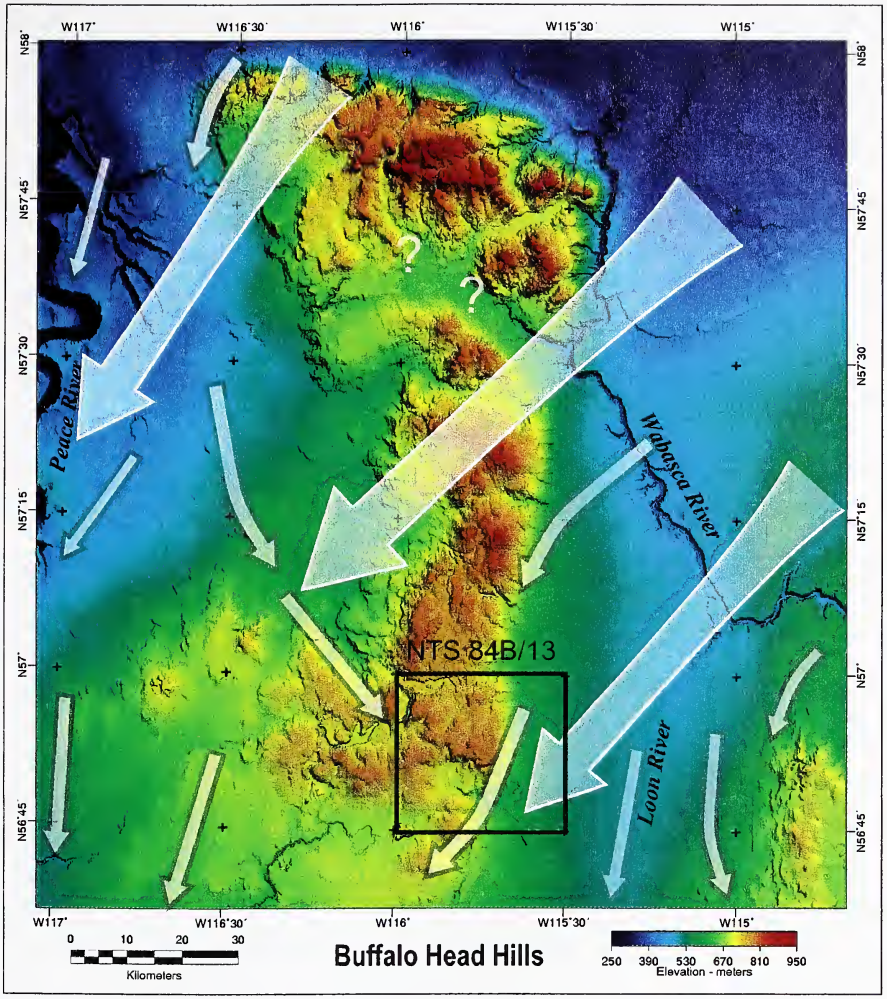


Figure 32. Interpreted ice flow for the Buffalo Head Hills based on till fabric studies completed by the Alberta Geological Survey 1996-2003. (From Paulen *et al.* 2003d)

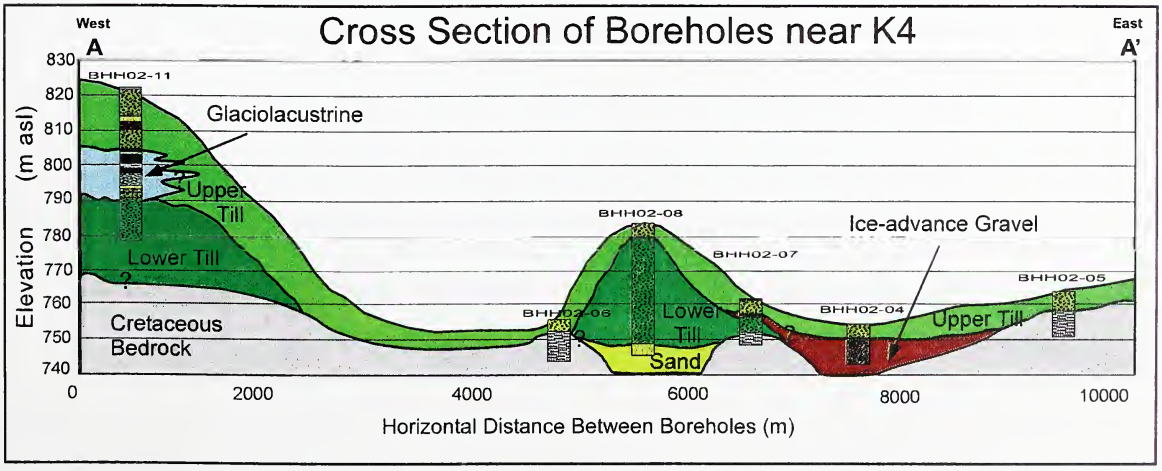


Figure 33. Schematic cross-section of stratigraphy near K4 kimberlite. Based on drill hole data provided by John Pawlowicz. Note occurance of two tills.

Deglaciation: Hummock Formation

Debate exists as to formation of hummocks and doughnuts, ranging from subglacial squeezing of basal till (Stalker 1960; Eyles *et al.* 1999; Boone and Eyles 2001) to supraglacial sediment infilling around stagnating ice blocks (Gravenor 1955; Gravenor and Kupsch 1959, Johnson *et al.* 1995) to origin as a subglacial erosional landform (Munro and Shaw 1997, Beaney and Shaw 2000).

A purely subglacial origin (Figure 34) requires basal till material to form the doughnut ring, through a process of differential melting and ice thicknesses. Variable ice thickness results in differential stresses and variable melt rates that affect the substrate materials, leading to deformation / squeezing of the underlying basal till (Boone and Eyles 2001). Lithologically, this mechanism requires that hummocks be formed not only from basal till, but also glaciotectonized bedrock/underlying sediment (Eyles *et al.* 1999). Stalker (1960) and Eyles *et al.* (1999) consider that washboard moraine, drumlin and hummock landforms are closely related landforms of a "subglacial continuum" whereby subglacial deformation occurs during both advance and retreat, with some modification of initial landforms.

In contrast, a supraglacial origin (Figure 35) requires supraglacial sediment to either accumulate preferentially within ice depressions or be deposited through ablation in regions of variable ice thickness/debris load. This mechanism of topographic inversion creates kame and kettle collapse topography as buried stagnant ice differentially melts, leaving sediment highs and waterlain lows (Ham and Attig 1996). Lithologically,

Johnson *et al.* (1995) map hummocks consisting of a combination of diamicton, and poorly stratified sand and gravel interpreted as "melt-out till, flow till, meltwater-stream sediment…lake sediment and debris-flow sediment."

Of the subglacial erosional model (Figure 36), Beaney and Shaw (2000) propose that hummocks can be explained by differential subglacial meltwater erosion in regions of lower velocity flow vortices. This model is based on hummock outcrops cored by truncated bedrock and capped by discontinuous till remnants (Munro and Shaw 1997). The lithology of those particular southern Alberta hummocks is distinctly different from those observed in the Sawn Lake field area. It is unlikely that the erosional hypothesis applies here as the observed lithology is better explained by a different mechanism.

Most geomorphological features are polygenetic and it is likely that the doughnuts formed as a combination of above processes (Mollard 2000). However, field observations at site MT03-176 indicate a preference for the subglacial squeezing hypothesis, given that the doughnut walls are predominately weathered/unweathered till with only local glaciofluvial deposition. In combination with the presence of continuous till throughout the map area that likely underlies stagnant ice moraine (Borehole 8 Appendix B), a deformable substrate is provided for the subglacial squeezing model during stagnation. It is noted that the stagnant ice hummocks within the map area are not associated with washboard moraine or drumlins, but do occur on a topographic upland. The supraglacial model for hummock formation likely explains certain geomorphologic landforms, but it is difficult to imagine such a process creating the precise circular

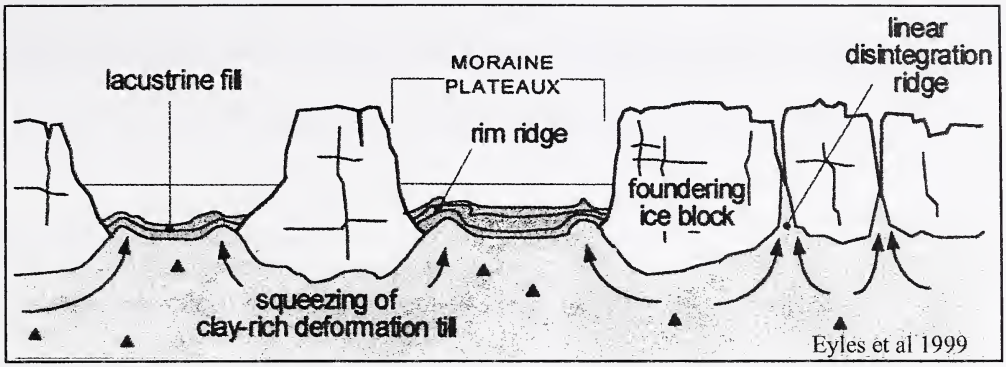


Figure 34. Subglacial squeezing model. Hummocks and doughnut rings formed by ice-pressure with occasional lacustrine infilling of sediment. Note association with moraine plateaux and linear disintegration ridges. Lithology of hummocks is clay-rich basal/deformation till. (From Eyles *et al.* 1999)

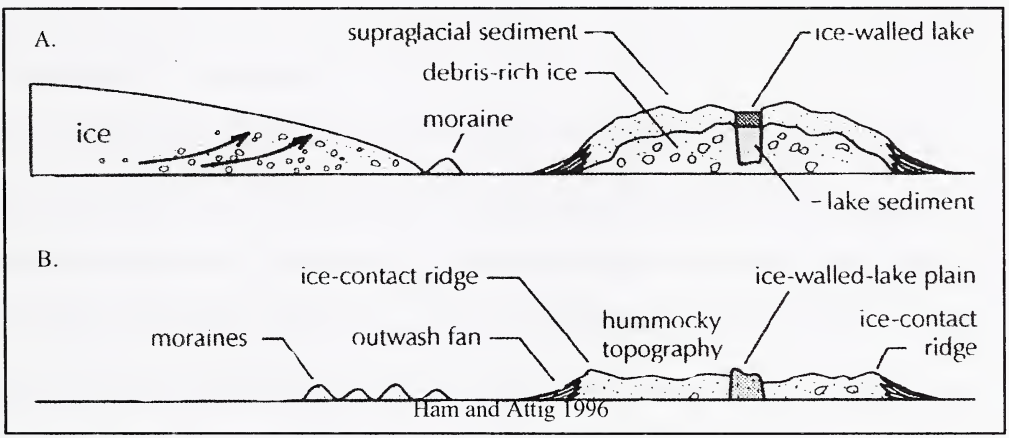


Figure 35. Supraglacial meltdown model. A) First stage- stable phase creating a zone of buried, stagnant ice. Formation of ice-walled lakes occur during this stage as supraglacial lakes melt down to the bed. B) Second stage- unstable phase whereby buried ice melts and deposits sediments in a collapse method, forming hummocks due to the uneven distribution of ice and debris. (From Ham and Attig, 1996)

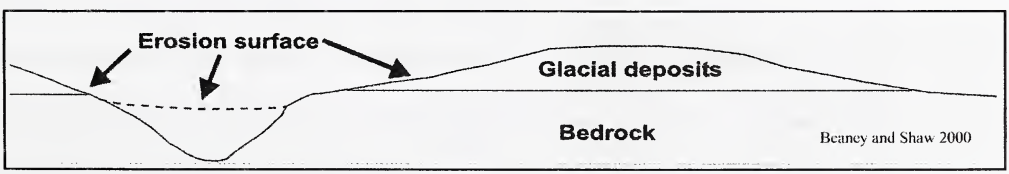


Figure 36. Subglacial erosion model. Modified sketch based on outcrop in southern Alberta. Where an "erosional surface truncates Late Cretaceous sandstone and shale and glacial deposits, producing hummocky terrain. Erosion also produces a flat topographic surface where flow velocities were increased." (From Beaney and Shaw, 2000)

doughnut hummocks seen in the map area (Figure 17). Further sections are required to study the lithologic and stratigraphic variance of hummocks within the map area.

Deglaciation: Crevasse Fill

Boone and Eyles (2001) state that crevasse fills can form by the same subglacial squeezing process as hummocks. A subglacial till squeezing mechanism could account for their occurrence within/overlying till plains, and may record ice retreat/stagnation processes on the flanks of the Buffalo Head Hills in the southwest map area.

Deglaciation: Ice-walled Lake

Ham and Attig (1996) document ice-walled lake plains in north-central Wisconsin, but their sizes range from 1- 4 km diameter and thus a comparison with this map area is limited. It is interesting to note that Ham and Attig (1996) cite an intimate association between ice-walled lake plains during periods of stability and hummocky debris deposition during unstable melt periods (also Clayton and Cherry 1967). The suspect ice-walled lake forms of the Sawn Lake region occur within an organic plain, surrounded by glaciofluvial material and interpreted as an outwash plain. Perhaps they represent late-stage stagnation and melt in a low-debris environment with subsequent low-energy melt and lake drainage allowing preservation of the raised geomorphic forms. It is also possible that the forms represent erosional remnants created during subglacial or proglacial meltwater flow and are not stagnation features. Detailed topographic and lithologic survey of the surrounding region is required to confidently interpret these features. However, their high (relative) relief, geomorphic shape and undisturbed

horizontal bedding preferentially support interpretation as ice-walled glaciolacustrine sediments.

Deglaciation: Timing of Meltwater Flow and Deposition

Three eskers are mapped within the central region of glaciofluvial sediment. Stratigraphy and lithology underlying these eskers is uncertain, but landform relationships hint at a subglacial model. The eskers were formed subglacially, and it is plausible that they formed in association with the surrounding hummocky to flat-lying glaciofluvial deposits, accounting for topography and polygon shape. The eskers do not appear eroded or dissected, as would be expected during a period of proglacial flow significant enough to deposit the surrounding glaciofluvial sediment. Minor meltwater channels incise the large central glaciofluvial polygons, which regardless of channel origin (subglacial, proglacial or ice-marginal) require close presence of ice for their development. This further suggests that the mapped glaciofluvial plains may actually be ice-contact, subglacially deposited sediment. There appears to be a rough northwest flow trend, defined mainly by organics, from these central polygons to an organic/glaciofluvial plain in the southwestern map region.

It is possible that this southwestern organic plain overlies glaciofluvial and glaciolacustrine deposits, as the topography is variable and organics are usually expected to form only in lows, not as large topographically variable polygons. This southwestern organic/glaciofluvial plain is only dissected by one meltwater channel, though the long, narrow organic polygons appear to delimit larger channel paths. There are at least two

episodes of meltwater, with N-S trending channels cross-cutting E-W channels. A third northwest-trending episode exists at a larger scale and may be related to earlier sub-glacial flow. This flow is not extensive, as the glaciofluvial plain/organics quickly dissipate into a low-lying glaciolacustrine region in NTS 84C/16 (Paulen *et al.* 2004).

Further stratigraphic and lithologic relations are required to confidently describe the origin of the central and southwestern region of glaciofluvial sedimentation, however field relations seem to favour a subglacial model of deposition.

Recession

Recession began around 14 ka BP (Dyke *et al.* 2003) for the northwest, southwest and south margins of the Laurentide ice sheet. Northeast of the Sawn Lake map-area, gyttja has been dated from the Birch Mountain Hills (Mariana Lake) at 11,300±110 (GSC-2038, Lowdon *et al.* 1977, Jackson and Pawson 1984). Further west, bison bones were dated at Watino to be 10,200±100 (GSC-2895, Westgate *et al.* 1972). These dates are interpreted as minimum ages for deglaciation for northern Alberta, and record the colonization of Pleistocene mammals after the last glaciation.

ENGINEERING GEOLOGY

Identification of surficial material is important in the Sawn Lake region due to increasing oil, gas and mineral exploration activity. Moraine is the local road building material owing to the variety of grain sizes within. This map will enable easier location of suitable materials for future burrow pits during construction. It is important to note that

Figure 37. Flooded well site due to construction within a poorly drained bog, underlain by fine-grained mineral soil.

Figure 38. Gravel discovered at site MT03-005 during well site construction were used to maintain the roads for durability during wet periods.

while moraine is suitable for roads in dry conditions, the clay content of till is high, which leads to swelling, lack of infiltration and loss of cohesion when wet. Glaciolacustrine sediments must be avoided as road and well site construction material for this reason, given that the region is susceptible to wet periods (Figure 37). Also, potential road instability may occur in areas of poor water drainage and where roads have been constructed on colluvium. Gravel for road maintenance is associated with glaciofluvial sediments and preglacial gravel in the map area, and is used when possible (Figure 38). The esker located along the road between sites MT03-098 and -099 is currently being quarried for granular aggregate.

IMPLICATIONS FOR MINERAL EXPLORATION

As of 2003, thirty-eight kimberlites had been discovered within the Buffalo Head Hills (Eccles *et al.* 2003) including K-4, -5, -6, -7, -8, -14, -91, -95, -252, WP and TQ155 in the Sawn Lake Map area. Recent exploration has added K-296, -300, BH229 and BH225 within the map area (Figure 39). Delineating ideal sample media for indicator mineral sampling is important given the sediment and geologic differences in moraine versus stagnant ice moraine. Identification of basal till is difficult but provides a more defined clast fabric and is likely more accurate in determining local ice flow and deciphering dispersal trains (Fenton *et al.* 2003c). However, in areas of high clay content, stagnant ice moraine may possess a greater coarse fraction for quick sampling, but may include englacial debris with a distal provenance. For reconnaissance sampling, recognition of ice-contact glaciofluvial sediment is also important in determining kimberlite potential.

For example, an esker south and east of the kimberlites contains not only indicator minerals, but kimberlitic pebbles and cobbles.

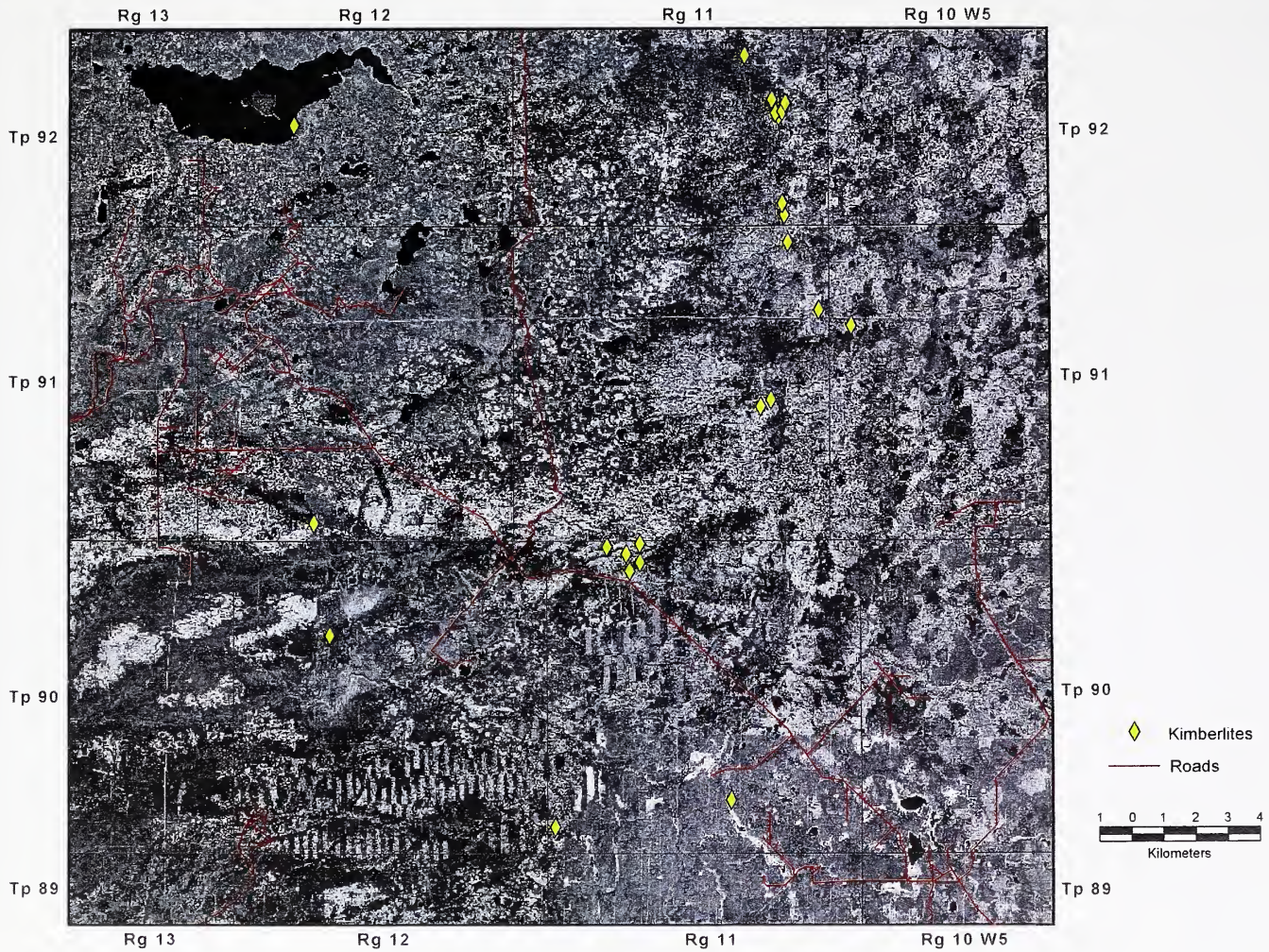


Figure 39. Map of showing known kimberlite locations within the Buffalo Head Hills, for the Sawn Lake Map Region.

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APPENDIX A

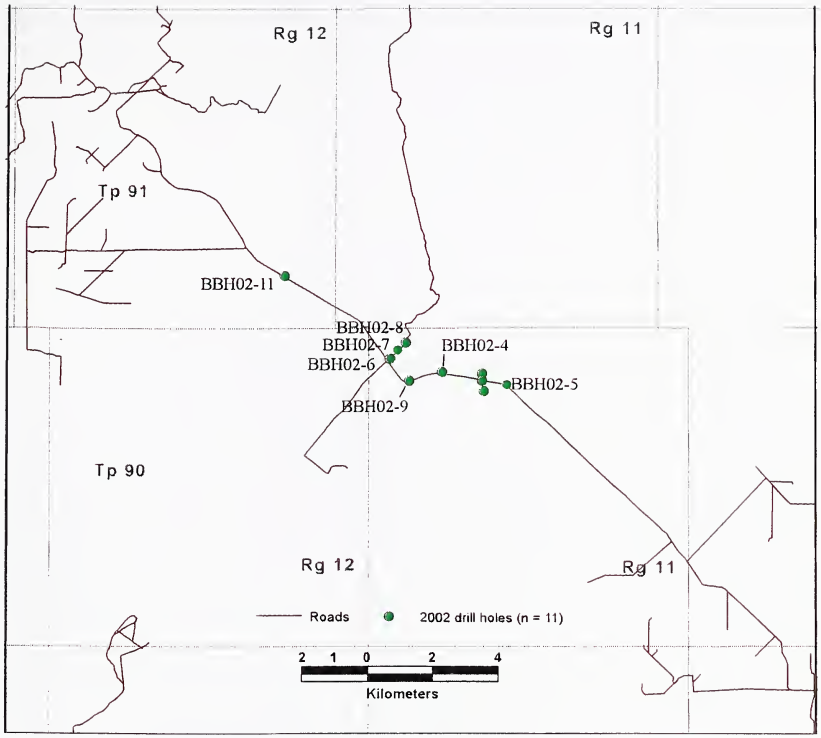
Site	Time	Travel	NTS250	System	Northing	Easting	Position	Vegetation	Major Veg	Minor Veg	Geomorph	Relief	Source	SiteDesc	UnitNo	Lithology	Genesis
MT03-001	8/15/2003	land	84B	UTM NAD83	6301857	564546	flat				plain	0-2 m	burrow pit	Borrow site BRK-1, Wollitt gulf bedrock	1	diamicton	till
															2	sandstone	bedrock
MT03-002	8/15/2003	land	84B	UTM NAD83	6301780	564105							burrow pit		1	diamicton	till
															2	sandstone	bedrock
MT03-003	8/15/2003	land	84B	UTM NAD83	6303603	563696	hilltop				hummock(s)		section	Roadcut hummock in new wellsite.	1	diamicton	till
															2	sand & gravel	uncertain
MT03-004	8/15/2003	land	84B	UTM NAD83	6303464	563739							burrow pit	Gravels dredged up from bottom of pit	1	diamicton	till
															2	sand & gravel	uncertain
MT03-005	8/15/2003	land	84B	UTM NAD83	6303412	563895					hummock(s)	2-5 m	road cut	Hummock cut into during wellsite construction. Section only preserved for a few days	1	diamicton	till
															2	sand & gravel	uncertain
MT03-006	8/8/2003	land	84B	UTM NAD83	6308258	589599	flat	forest-deciduous	poplar	white spruce	plain	0-2 m	probe	Probed at edge of wetland	1	diamicton	till
MT03-007	8/8/2003	land	84B	UTM NAD83	6308294	590132	flat	forest-deciduous	poplar		plain	0-2 m	probe	Probed in poplars at point of heighest elev	1	diamicton	till
MT03-008	8/8/2003	land	84B	UTM NAD83	6308239	590498	flat	wetland	black spruce	sphagnum	plain	0-2 m	probe	Classic black spruce bog that has drained.	1	peat	wetland
														Caribou moss on surface. Labrador Tea present	2	clayey silt	
MT03-009	8/8/2003	land	84B	UTM NAD83	6306559	590537	flat	forest-deciduous	poplar		plain	0-2 m	probe		1	diamicton	till
MT03-010	8/8/2003	land	84B	UTM NAD83	6303851	590607	flat	forest-deciduous	poplar		plain	0-2 m	probe		1	diamicton	till
MT03-011	8/8/2003	land	84B	UTM NAD83	6303364	588641	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe		1	diamicton	till
MT03-012	8/8/2003	land	84B	UTM NAD83	6300521	586311	flat	wetland	black spruce	tamarack	plain	0-2 m	probe		1	peat	wetland
															2	silty clay	
MT03-013	8/8/2003	land	84B	UTM NAD83	6300402	586934	flat	forest-mixed	white spruce	poplar	plain	0-2 m	probe		1	diamicton	till
															2	sand	glaciolacustrine
MT03-014	8/8/2003	land	84B	UTM NAD83	6300381	587439	flat	forest-mixed	poplar	white spruce	plain	0-2 m	section		1	diamicton	till
MT03-015	8/8/2003	land	84B	UTM NAD83	6298735	590979	flat	forest-deciduous	poplar		plain	0-2 m	probe		1	sand	
															2	diamicton	till
MT03-016	8/8/2003	land	84B	UTM NAD83	6297630	591076	flat	forest-mixed	poplar	white spruce	plain	0-2 m	road cut		1	diamicton	till
MT03-017	8/8/2003	land	84B	UTM NAD83	6297778	591958	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe		1	sand	glaciolacustrine
MT03-018	8/8/2003	land	84B	UTM NAD83	6297199	591990	flat	forest-mixed	white spruce	black spruce	plain	0-2 m	auger	boulder leg present between sand and till	1	sand	glaciolacustrine
															2	diamicton	till
MT03-019	8/8/2003	land	84B	UTM NAD83	6296634	591308	flat	forest-deciduous	poplar		undulating	0-2 m	probe		1	diamicton	till
MT03-020	8/8/2003	land	84B	UTM NAD83	6295784	590517	flat	forest-conifer	white spruce	poplar	undulating	0-2 m	probe	Probed in very mature spruce forest on top of a series of small undulations.	1	sand	
															2	diamicton	till
MT03-021	8/8/2003	land	84B	UTM NAD83	6295033	589828	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe		1	diamicton	till
MT03-022	8/8/2003	land	84B	UTM NAD83	6293918	589886	flat	forest-deciduous	poplar		plain	0-2 m	probe	Poplar ragrowth of forested eras	1	diamicton	till
MT03-023	8/8/2003	land	84B	UTM NAD83	6293101	589430	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe		1	diamicton	till
MT03-024	8/8/2003	land	84B	UTM NAD83	6292968	588533	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe		1	diamicton	till
MT03-025	8/8/2003	land	84B	UTM NAD83	6292510	588403	flat	forest-deciduous	poplar		plain	0-2 m	road cut	Section along ditch	1	diamicton	till
MT03-026	8/8/2003	land	84B	UTM NAD83	6292957	587804	flat	forest-mixed	white spruce	poplar	plain	0-2 m	probe	probed in northwest corner of old wellsite	1	diamicton	till
MT03-027	8/8/2003	land	84B	UTM NAD83	6290218	587963	flat	forest-deciduous	poplar		undulating	0-2 m	probe	probed in forest north of an old wellsite	1	diamicton	till
MT03-028	8/8/2003	land	84B	UTM NAD83	6291265	587873	flat	forest-deciduous	poplar		plain	0-2 m	drive by	Stones in ditch	1	diamicton	till
MT03-029	8/8/2003	land	84B	UTM NAD83	6290665	589716	flat	forest-mixed	white spruce	poplar	plain	0-2 m	probe	probed in forest; bog all around	1	diamicton	till
MT03-030	8/9/2003	land	84B	UTM NAD83	6300717	564234	flat	wetland	black spruce	pine	undulating	0-2 m	wellsite	new well sits (2002) flooded, peat and till dug up everywhere	1	peat	wetland
															2	diamicton	till
MT03-031	8/9/2003	land	84B	UTM NAD83	6302507	563734	hill flank	forest-deciduous	poplar		undulating	0-2 m	probe	Probed in poplars on flank of series of building undulations.	1	diamicton	till
MT03-032	8/9/2003	land	84B	UTM NAD83	6304039	563877	flat	forest-conifer	pine		undulating	0-2 m	probe	probed at east end of an old wellsite; almost all pine;	1	silt	glaciolacustrine
MT03-033	8/9/2003	land	84B	UTM NAD83	6308731	564379	hill bottom	wetland	pine	poplar	gullie(s)	0-2 m	probe	old wellsite at base of very large topo low (outwash plain?)	1	sandy silt	
MT03-034	8/9/2003	land	84B	UTM NAD83	6306364	565026	hill flank	forest-deciduous	poplar		hummock(s)	2-5 m	road cut	road intersects till hummock	1	diamicton	till
MT03-035	8/9/2003	land	84B	UTM NAD83	6305655	564881	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	section	Trench over leaking pipeline, not sure if in situ	1	clay	
MT03-036	8/9/2003	land	84B	UTM NAD83	6305013	565551					hummock(s)	0-2 m	road cut		1	diamicton	till
MT03-037	8/9/2003	land	84B	UTM NAD83	6304829	564865	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	probe	probed just off intersection in forest	1	diamicton	till
MT03-038	8/9/2003	land	84B	UTM NAD83	6304230	564598	flat	wetland	black spruce	sphagnum	plain	0-2 m	probe	probed at southeast edge of old wellsite in spruce stand	1	silt	
															2	diamicton	till
MT03-039	8/9/2003	land	84B	UTM NAD83	6305517	566096	hill bottom	wetland	marsh grass	black spruce	gullie(s)	>5 m	probe		1	peat	wetland
MT03-040	8/9/2003	land	84B	UTM NAD83	6305179	566056	hill flank	forest-deciduous	poplar		gullie(s)	>5 m	section	section through hummock, possibly old pit	1	diamicton	till
MT03-041	8/9/2003	land	84B	UTM NAD83	6303253	566155	flat	forest-mixed	white spruce	poplar	undulating	0-2 m	road cut		1	diamicton	till
MT03-042	8/9/2003	land	84B	UTM NAD83	6302893	564816	hill flank	forest-deciduous	poplar		hummock(s)	2-5 m	road cut		1	diamicton	till
MT03-043	8/9/2003	land	84B	UTM NAD83	6303591	565441	hill flank	forest-deciduous	poplar		hummock(s)	2-5 m	road cut		1	diamicton	till
MT03-044	8/9/2003	land	84B	UTM NAD83	6304233	565761	flat	forest-mixed	white spruce	poplar	hummock(s)	0-2 m	burrow pit	road cut through hummock and water-filled burrow pit	1	diamicton	till
MT03-045	8/9/2003	land	84B	UTM NAD83	6304996	569673	hill flank	forest-mixed	poplar	black spruce	hummock(s)	0-2 m	probe	Probed north of road 7m into poplar forest	1	diamicton	till
MT03-046	8/9/2003	land	84C	UTM NAD83	6305396	559792	flat	forest-conifer	black spruce	pine	hummock(s)	2-5 m	road cut	in 84C18	1	silt	uncertain
															2	diamicton	till
MT03-047	8/9/2003		84B		6305973	561603			poplar		hummock(s)		burrow pit	cuts into hummock on SE corner	1	diamicton	till
MT03-048	8/9/2003		84B		6307695	562228	flat	forest-conifer	pine		plain				1	sand	glaciofluvial
MT03-049	8/9/2003	land	84B	UTM NAD83	6307613	582376	flat	forest-conifer	pine	black spruce	hummock(s)	0-2 m	road cut	hummock on south side of road	1	diamicton	till
MT03-050	8/9/2003	land	84B	UTM NAD83	6307934	562652	flat	forest-conifer	pine	poplar	hummock(s)	0-2 m	section	section into hummock on east side of road	1	diamicton	till
MT03-051	8/9/2003	land	84B	UTM NAD83	6311874	562634	flat	forest-conifer	black spruce	pine	plain	0-2 m	probe	Probed on east side of road	1	diamicton	till
MT03-052	8/9/2003	land	84B	UTM NAD83	6310900	562362	flat	forest-deciduous	poplar	white spruce	hummock(s)	0-2 m	road cut	section on west side of road	1	diamicton	till
MT03-053	8/9/2003	land	84B	UTM NAD83	6309000	562625	hill flank	forest-deciduous	poplar	white spruce	hummock(s)	>5 m	road cut	road cuts through a hummock, which is very steep-sided to the south	1	sand & gravel	glaciofluvial
														(on the valley edge of a channel)	2	diamicton	till

Site	Time	Travel	NTS250	System	Northing	Easting	Position	Vegetation	Major Veg	Minor Veg	Geomorph	Relief	Source	SiteDesc	UnitNo	Lithology	Genesis
MT03-054	8/9/2003		84B		6310021	564602			poplar				probe	Probed 100m north of wellsite in forest	1	diamicton	till
MT03-055	8/9/2003		84B		6313939	564973	flat	forest-mixed	pine		undulating		probe	attempted to get to lake, but road too bad. Probed	1	silt	uncertain
														in baby pine forest	2	diamicton	till
MT03-056	8/9/2003		84B		6313329	564979	flat				hummock(s)	0-2 m	road cut	section into hummock as before	1	diamicton	till
MT03-057	8/9/2003		84B		6311983	564982	flat				hummock(s)	0-2 m	road cut	same as 56	1	diamicton	till
MT03-058	8/9/2003		84B		6311511	565411					hummock(s)	2-5 m	section	section on side of wellsite	1	diamicton	till
MT03-059	8/12/2003	land	84B	UTM NAD83	6309087	565606			pine				ditch cut	baby pins forest, on edge of channel	1	sand	glaciofluvial
															2	diamicton	till
MT03-060	8/12/2003	land	84B	UTM NAD83	6309649	566419		forest-mixed	poplar	white spruce			probe	Probed 6m north of road	1	silt	uncertain
															2	diamicton	till
MT03-061	8/12/2003	land	84B	UTM NAD83	6311727	567656					hummock(s)	2-5 m	section	till hummock on southeast edge of wellsite	1	diamicton	till
MT03-062	8/12/2003	land	84B	UTM NAD83	6310853	567758					hummock(s)	0-2 m	probe	probed east of road into large till hummock	1	diamicton	till
MT03-063	8/12/2003	land	84B	UTM NAD83	6310644	568205			pine		hummock(s)	0-2 m	road cut	Old wellsite cut into hummock on northeast side of road	1	diamicton	till
MT03-064	8/12/2003	land	84B	UTM NAD83	6309619	567833					hummock(s)		road cut		1	diamicton	till
MT03-065	8/12/2003	land	84B	UTM NAD83	6309304	566513		forest-mixed	poplar	pine	plain	0-2 m	probe	Probed on west side of road, under a fallen tree	1	diamicton	till
MT03-066	8/12/2003	land	84B	UTM NAD83	6308572	566668	flat				plain	0-2 m	pelins exposure		1	diamicton	till
MT03-067	8/12/2003	land	84B	UTM NAD83	6307997	566153					undulating	0-2 m	ditch section	20m long ditch section near wellsite	1	diamicton	till
MT03-068	8/12/2003	land	84B	UTM NAD83	6307718	565647					hummock(s)		road cut		1	diamicton	till
MT03-069	8/12/2003	land	84B	UTM NAD83	6307982	566594	hilltop		poplar		hummock(s)	>5 m	road cut	till hummock (6.5m high by 25m width) on southwest edge of channel	1	diamicton	till
MT03-070	8/12/2003	land	84B	UTM NAD83	6307469	567199					hummock(s)	0-2 m	road cut		1	diamicton	till
MT03-071	8/12/2003	land	84B	UTM NAD83	6306903	568325		forest-mixed	poplar	white spruce		0-2 m	probe		1	diamicton	till
MT03-072	8/12/2003	land	84B	UTM NAD83	6305855	569857		forest-mixed	poplar	white spruce			probe		1	diamicton	till
MT03-073	8/12/2003	land	84B	UTM NAD83	8309337	574908		forest-conifer	pine	white spruce	undulating	0-2 m	probe		1	clay	uncertain
															2	diamicton	till
MT03-074	8/12/2003	land	84B	UTM NAD83	8308930	575029					hummock(s)	0-2 m	road cut		1	diamicton	till
MT03-075	8/12/2003	land	84B	UTM NAD83	6308429	575140					hummock(s)	0-2 m	auger		1	diamicton	till
															2	clay	uncertain
MT03-076	8/12/2003	land	84B	UTM NAD83	6309002	575093		forest-conifer	pine		plain	0-2 m	auger	dug hole and auger on quad trail	1	sand	uncertain
MT03-077	8/12/2003	land	84B	UTM NAD83	6307604	574782		forest-conifer	white spruce	tamarack	plain	0-2 m	probe	probed on seismic line	1	sand	uncertain
MT03-078	8/12/2003	land	84B	UTM NAD83	6307214	575275		forest-conifer	poplar	white spruce	undulating		probe	on quad trail	1	diamicton	till
MT03-079	8/12/2003	land	84B	UTM NAD83	6306835	575361					hummock(s)	0-2 m	probe	small hummock road cut right before very wet bog, probed on trail	1	diamicton	till
MT03-080	8/12/2003	land	84B	UTM NAD83	6306561	575877							probe	probed as far as we got down on seismic line	1	diamicton	till
MT03-081	8/12/2003	land	84B	UTM NAD83	6306061	575583					hummock(s)	0-2 m	auger	probed and augered on high in quad trail, between 2 bogs	1	diamicton	till
MT03-082	8/12/2003	land	84B	UTM NAD83	6305462	575778									1	diamicton	till
MT03-083	8/12/2003	land	84B	UTM NAD83	6305034	575871			black spruce		plain	0-2 m	got stuck in it		1	peat	wetland
MT03-084	8/12/2003	land	84B	UTM NAD83	6304248	576083							drive by	very small hummock,middle bog , quad trail has boulder pavement	1	diamicton	till
MT03-085	8/12/2003	land	84B	UTM NAD83	6303517	576271					hummock(s)	0-2 m	drive by	same as 84 with quad trail boulder pavement	1	diamicton	till
MT03-086	8/12/2003	land	84B	UTM NAD83	6302901	575543					undulating	0-2 m	auger		1	diamicton	till
MT03-087	8/12/2003	land	84B	UTM NAD83	6303801	576099							drive by		1	diamicton	till
MT03-088	8/12/2003	land	84B	UTM NAD83	6302022	575143					hummock(s)	0-2 m	drive by		1	diamicton	till
MT03-089	8/12/2003	land	84B	UTM NAD83	6304699	570778	hilltop	forest-mixed	poplar	white spruce	hummock(s)	2-5 m	road cut	Husky camp at heig lake	1	diamicton	till
MT03-090	8/12/2003	land	84B	UTM NAD83	6303908	571874	hilltop	forest-deciduous	poplar		hummock(s)	2-5 m	road cut	high point in the road	1	diamicton	till
MT03-091	8/12/2003	land	84B	UTM NAD83	6303251	573139	hill bottom	forest-mixed	pine	white spruce	hummock(s)	2-5 m	probe	at bottom of likely channel, small roadcut hummock	1	diamicton	till
MT03-092	8/12/2003	land	84B	UTM NAD83	6302026	574454	hill flank	forest-conifer	black spruce		hummock(s)	2-5 m	probe	probed channel side in a spruce bog	1	peat	wetland
															2	diamicton	till
MT03-093	8/12/2003	land	84B	UTM NAD83	6301110	575122		forest-deciduous	white spruce	black spruce	undulating	0-2 m	auger		1	diamicton	till
MT03-094	8/12/2003	land	84B	UTM NAD83	6300492	578899	hill bottom	forest-conifer	black spruce		undulating	0-2 m	probe	probed in left ditch	1	diamicton	till
MT03-095	8/12/2003	land	84B	UTM NAD83	8300046	579401	hill bottom	forest-conifer	white spruce	pine	hummock(s)	0-2 m	road cut	slight low in road, ditch cut	1	sand	glaciofluvial
MT03-096	8/12/2003	land	84B	UTM NAD83	6299802	579696	hilltop	forest-mixed	poplar	pine	ridge(s)	>5 m	road cut	likely esker, section is evident on both sides of the road	1	sand & gravel	glaciofluvial
MT03-097	8/12/2003	land	84B	UTM NAD83	6299233	580301	hill flank	forest-mixed	poplar	white spruce	undulating	0-2 m	road cut		1	sand	glaciofluvial
MT03-098	8/12/2003	land	84B	UTM NAD83	6298730	580800	hilltop	forest-mixed	poplar	white spruce	ridge(s)	>5 m	section	down hunting trail off main road. Ridges have 2-3m amplitude	1	sand	glaciofluvial
MT03-099	8/12/2003	land	84B	UTM NAD83	6297523	581983	flat	forest-conifer	pine	white spruce	hummock(s)	0-2 m	dug hole	hunting campground, off the main road	1	sand	glaciofluvial
MT03-100	8/12/2003	land	84B	UTM NAD83	6297097	581648	hilltop	forest-conifer	pine	white spruce	gullis(s)	>5 m	drive by	down hunting road	1	sand	glaciofluvial
MT03-101	8/12/2003	land	84B	UTM NAD83	8296871	582952	hill flank	forest-deciduous	poplar		hummock(s)	0-2 m	road cut		1	diamicton	till
MT03-102	8/12/2003	land	84B	UTM NAD83	6294952	580964	flat	forest-deciduous	poplar		plain	0-2 m	auger		1	sand	glaciofluvial
MT03-103	8/12/2003	land	84B	UTM NAD83	6294188	581762	flat	forest-deciduous	poplar		undulating	0-2 m	hole dug	new (moved?) wellsite. Roger febric? About 100m west of TQ155	1	diamicton	till
MT03-104	8/12/2003	land	84B	UTM NAD83	6295730	582909	flat	forest-mixed	white spruce	poplar	plain	0-2 m	probe		1	sand	glaciofluvial
MT03-105	8/12/2003	land	84B	UTM NAD83	6296280	583493	flat	forest-deciduous	poplar		plain	0-2 m	probe	probed at intersection	1	sand	glaciofluvial
															2	diamicton	till
MT03-106	8/12/2003	land	84B	UTM NAD83	6298595	585956	flat	forest-deciduous	poplar		plain	0-2 m	probe	probed at northeast adge of wellsite	1	silt	glaciofluvial
MT03-107	8/12/2003	land	84B	UTM NAD83	6297513	587753	flat	forest-mixed	black spruce	poplar	undulating	0-2 m	probe		1	diamicton	till
MT03-108	8/12/2003	land	84B	UTM NAD83	6297591	587046	flat	forest-deciduous	poplar		plain	0-2 m	burrow pit	2 overgrown pits on either side of road	1	diamicton	till
MT03-109	8/12/2003	land	84B	UTM NAD83	6296377	588464	flat	wetland	temarack	sphegnum	plain	0-2 m	probe	all temarack, photo	1	peat	wetland
MT03-110	8/12/2003	land	84B	UTM NAD83	6296823	586551	flat	forest-conifer	pine		undulating	0-2 m	auger	pipeline exposure and auger. Sita is at start of sand and pine forest	1	sand	glaciofluvial
MT03-111	8/12/2003	land	84B	UTM NAD83	6297085	586547	flat	forest-deciduous	poplar		ridge(s)	0-2 m	auger	appears to be a sort of fluvial doughnut; in the middle of the pine forest	1	sand	glaciofluvial
MT03-112	8/12/2003	land	84B	UTM NAD83	6298225	586960	flat	forest-mixed	poplar	white spruce	plain	0-2 m	burrow pit	Vegetated and water-filled burrow pit	1	diamicton	till
MT03-113	8/12/2003	land	84B	UTM NAD83	6296526	584745	flat	forest-mixed	poplar	white spruce	plain	0-2 m	probe	probed along road in forest	1	diamicton	till
MT03-114	8/12/2003	land	84B	UTM NAD83	6294981	584474						0-2 m	burrow pit	2 old vegetated pits	1	diamicton	till

Site	Time	Travel	NTS250	System	Northing	Easting	Position	Vegetation	Major Veg	Minor Veg	Geomorph	Relief	Source	SiteDesc	UnitNo	Lithology	Genesis
MT03-115	8/12/2003	land	84B	UTM NAD83	6295708	586369	flat	forest-mixed	black spruce	poplar	plain	0-2 m	probe	new road to new wellsite, probed at SE edge of it	1	diamicton	till
MT03-116	8/15/2003	land	84B	UTM NAD83	6309700	589271		forest-deciduous	poplar		undulating	0-2 m	probe	attempted pipalma to K6, took site out of fan in forest	1	diamicton	till
MT03-117	8/15/2003	land	84B	UTM NAD83	6309312	587902	flat	wetland	willow	marsh grass	plain	0-2 m	stuck in it		1	peat	wetland
MT03-118	8/15/2003	land	84B	UTM NAD83	6309307	587955	flat	forest-mixed	poplar	black spruce	undulating	0-2 m	probe	on small poplar stand that comes from the north into the fan	1	diamicton	till
MT03-119	8/15/2003	land	84B	UTM NAD83	6309007	588894		forest-mixed	poplar	white spruce	plain	0-2 m	probe	probed at intersection of seismic lines	1	diamicton	till
MT03-120	8/15/2003	land	84B	UTM NAD83	6308274	588920		forest-mixed	poplar	white spruce	plain	0-2 m	probe	start of poplar stand, bog to the north	1	diamicton	till
MT03-121	8/15/2003	land	84L	UTM NAD83	6308134	588038		forest-mixed	marsh grass	poplar			probe	at the edge of another fan, photos	1	peat	wetland
															2	silt	uncertain
MT03-122	8/15/2003	land	84B	UTM NAD83	6308242	589585		forest-mixed	poplar	white spruce	undulating	0-2 m	probe	same site as MT-006. Probed at edge of fan	1	diamicton	till
MT03-123	8/15/2003	land	84B	UTM NAD83	6307112	590155		forest-deciduous	poplar		plain	0-2 m	probe	down southwest seismic line off of road	1	diamicton	till
MT03-124	8/15/2003	land	84B	UTM NAD83	6298126	583989			poplar		hummock(a)	0-2 m	probe	probed on qued trail, just south of uncrossable stream	1	sand	glaciofluvial
MT03-125	8/15/2003	land	84B	UTM NAD83	6297917	583203		forest-mixed	poplar	white spruce	hummock(s)	2-5 m	probe		1	diamicton	till
MT03-126	8/15/2003	land	84B	UTM NAD83	6297561	583000		forest-mixed	poplar	white spruce	undulating	0-2 m	probe	probed on qued trail	1	sand	glaciofluvial
MT03-127	8/15/2003	land	84B	UTM NAD83	6298761	582715		forest-mixed	poplar		hummock(a)	0-2 m	auger		1	sand	glaciofluvial
MT03-128	8/15/2003	land	84B	UTM NAD83	6298559	582241		forest-conifer	pine		undulating	0-2 m	auger	on south seismic line	1	sand	glaciofluvial
MT03-129	8/15/2003	land	84B	UTM NAD83	6299157	582101			pine	black spruce	undulating	0-2 m	auger	sort of in dried bog	1	sand & graval	glaciofluvial
MT03-130	8/15/2003	land	84B	UTM NAD83	6301753	584055		forest-mixed	poplar		hummock(s)	2-5 m	probe	didn't quite reach esker looking feature	1	diamicton	till
MT03-131	8/15/2003	land	84B	UTM NAD83	6300969	583379			poplar		plain	0-2 m	auger		1	clay	glaciolacustrine
															2	sand & gravel	glaciofluvial
															1	sand & gravel	glaciofluvial
MT03-132	8/15/2003	land	84B	UTM NAD83	6300932	583348		forest-mixed	poplar	white spruce	undulating	0-2 m	auger		1	diamicton	till
MT03-133	8/15/2003	land	84B	UTM NAD83	6306041	582277		forest-mixed	poplar		undulating	2-5 m	probe	on the edge of K5 A, 50 m from drillsite	1	diamicton	till
MT03-134	8/15/2003	land	84B	UTM NAD83	6305822	583198					undulating	0-2 m	probe	interestion of seismic lines	1	diamicton	till
MT03-135	8/15/2003	land	84B	UTM NAD83	6305032	583215			poplar		undulating	0-2 m	probe		1	diamicton	till
MT03-136	8/15/2003	land	84B	UTM NAD83	6304099	583242			poplar		undulating	0-2 m	probe	on high point in trail	1	diamicton	till
MT03-137	8/15/2003	land	84B	UTM NAD83	6303273	583240			poplar		undulating	0-2 m	probe	probed on trail	1	diamicton	till
MT03-138	8/15/2003	land	84B	UTM NAD83	6302511	583266		forest-mixed	poplar		plain	0-2 m	auger		1	clay	glaciolacustrine
															2	sand & gravel	glaciofluvial
MT03-139	8/15/2003	land	84B	UTM NAD83	6301522	583287			poplar				auger	seismic intersection	1	sandy silt	uncertain
MT03-140	8/15/2003	land	84B	UTM NAD83	6301090	583313							auger	large pile oxidized sand and graval at surface (likely from shot holes)	1	sand & graval	glaciofluvial
MT03-141	8/15/2003	land	84B	UTM NAD83	6300268	582834					ridge(s)	2-5 m	hole dug	on qued road	1	sand & graval	glaciofluvial
MT03-142	8/15/2003	land	84B	UTM NAD83	6299761	582455					ridge(s)	2-5 m	section	2.5m high ridge, lots graval and oxidized sand at surface, 30 m section	1	sand & graval	glaciofluvial
MT03-143	8/15/2003	land	84B	UTM NAD83	6299036	581902							drive by		1	sand	glaciofluvial
MT03-144	8/15/2003	land	84B	UTM NAD83	6298512	581904					ridge(s)	0-2 m	auger		1	silt	uncertain
MT03-145	8/17/2003	land	84B	UTM NAD83	6291340	564101			pine	poplar	ridge(s)	2-5 m	section	at end of qued trail/ old wellsite road	1	sand	glaciofluvial
MT03-146	8/17/2003	land	84B	UTM NAD83	6292062	564087			white spruce	tamarac	plain		probe	probing in a baby high surrounded by wet bog	1	sand, silt	
MT03-147	8/17/2003	land	84B	UTM NAD83	6292495	564073			poplar	pine	plain	0-2 m	hole dug	out of low, on edge of old wellsite	1	silt	uncertain
															2	sand	glaciofluvial
MT03-148	8/17/2003	land	84B	UTM NAD83	6292513	563659		forest-mixed	pine	poplar			auger	west on seamics comin out of old wellsite	1	sand	glaciofluvial
MT03-149	8/17/2003	land	84B	UTM NAD83	6292647	565323			poplar		other	2-5 m	probe	little poplar stand with 3m relief, 30 wide, surrounded by bog	1	silt	glaciolacustrine
MT03-150	8/17/2003	land	84B	UTM NAD83	6292856	564077			black spruce	poplar	undulating	0-2 m	auger	not far from wellsite, but slight topo high. Numerous erratics at surface	1	sand	glaciofluvial
MT03-151	8/17/2003	land	84B	UTM NAD83	6293286	563784			poplar	white spruce	plain	0-2 m	auger	west on west seismic line	1	diamicton	till
MT03-152	8/17/2003	land	84B	UTM NAD83	6293374	566472			pine	poplar	plain	0-2 m	short note	east on seamic line, at old wellsite, Channel just to south of here	1	sand	glaciofluvial
MT03-153	8/17/2003	land	84B	UTM NAD83	6293340	566052			white spruce	poplar	plain	0-2 m	probe	on edge of channel	1	silt	glaciofluvial
															2	sand	glaciofluvial
MT03-154	8/17/2003	land	84B	UTM NAD83	6293327	565496			poplar	white spruce	plain	0-2 m	probe	near channel?	1	sand	glaciofluvial
MT03-155	8/17/2003	land	84B	UTM NAD83	6293267	565142					plain	0-2 m	burrow_pit	old burrow put on seamic line	1	silt	glaciofluvial
															2	sand	glaciofluvial
MT03-156	8/17/2003	land	84B	UTM NAD83	6293975	564084							probe	in large tall spruce bog, topography has a gradual climb to the north	1	diamicton	till
MT03-157	8/17/2003	land	84B	UTM NAD83	6294966	562531							auger	down NW, than SW seamic on channel edge	1	diamicton	till
MT03-158	8/17/2003	land	84B	UTM NAD83	6295598	563211						0-2 m	drive by	small hummock at intersection, large clests at surface	1	diamicton	till
MT03-159	8/17/2003	land	84B	UTM NAD83	6295611	564068					undulating	0-2 m		undulating just south, to ridge site is on. Boulders at surface last 500m	1	diamicton	till
MT03-160	8/17/2003	land	84B	UTM NAD83	6297023	564070					plain	0-2 m	auger	on a small till petch sticking out of bog	1	diamicton	till
MT03-161	8/17/2003	land	84B	UTM NAD83	6299310	564501					plain	>5 m	burrow_pit	Roger's 2001 bedrock pit, 200m west are 2 old, 3m till pits	1	diamicton	till
															2	transitional	till
															3	sandstone	bedrock
															4	mudstone	bedrock
MT03-162	8/17/2003	land	84B	UTM NAD83	6299293	565177			poplar				drive by		1	diamicton	till
MT03-163	8/17/2003	land	84B	UTM NAD83	6300343	564779			poplar	white spruce	ridge(s)	2-5 m	drive by	ridge out of bog, abundent clasts at surface	1	diamicton	till
MT03-164	8/18/2003	land	84B	UTM NAD83	6304226	582647					ridge(s)	>5 m	auger	on e-w seamic line, going west. Last 300m have bean increasing topography	1	sand & greval	glaciofluvial
MT03-165	8/18/2003	land	84B	UTM NAD83	6304738	582631							auger	Lots of esker ridges betwean here and there (poorly sorted sand and gravel)	1	diamicton	till
MT03-166	8/18/2003	land	84B	UTM NAD83	6304909	582833					ridge(s)	2-5 m		augered in unfilled shot hole, off hig ridges, but still on the flanks	1	diamicton	till
MT03-167	8/18/2003	land	84B	UTM NAD83	6304234	582949		forest-deciduous	poplar		undulating	0-2 m	auger	at point where ridges and crazy topography and (going east)	1	diamicton	till
MT03-168	8/18/2003	land	84B	UTM NAD83	6304826	582043		forest-mixed	poplar	white spruce	gullie(s)	>5 m	probe	going NW on a seamic line, past intersection. Up and down 3-4 gullies	1	diamicton	till
MT03-169	8/18/2003	land	84B	UTM NAD83	6303921	581784								on line south of wellsite	1	diamicton	till
MT03-170	8/18/2003	land	84B	UTM NAD83	6303826	581014	flat	forest-mixed	poplar	white spruce	other	2-5 m	auger	came west on a better seamic line from south 'wellsite road'	1	diamicton	till
MT03-171	8/18/2003	land	84B	UTM NAD83	6303330	581018	flat	forest-mixed	poplar	white spruce	plain	0-2 m	shot hole	following another crazy windy seamic line.	1	sand	glaciofluvial
MT03-172	8/18/2003	land	84B	UTM NAD83	6302880	581814	other	forest-conifer	white spruce	blue spruce	ridge(s)	0-2 m	auger	very ridged (possibly holocene gullies), probed at top of a ridge	1	diamicton	till

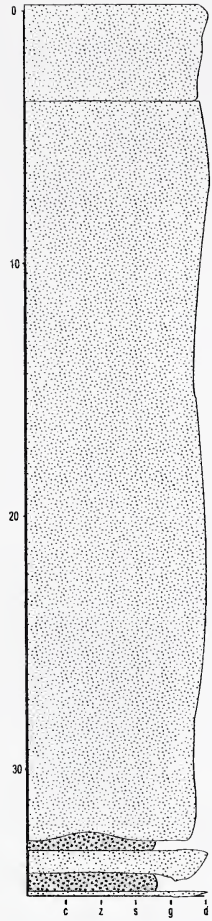
Site	Time	Travel	NTS250	System	Northing	Easting	Position	Vegetation	Major Veg	Minor Veg	Geomorph	Relief	Source	SiteDesc	UnitNo	Lithology	Genesis
MT03-173	8/18/2003	land	84B	UTM NAD83	6302107	581946		forest-mixed	white spruce	poplar	ridge(s)	>5 m	hend dug pit		1	sand	glaciofluvial
MT03-174	8/18/2003	land	84B	UTM NAD83	6301339	582097			poplar		ridge(s)	>5 m	section	Small section on top of 8m ridge	1	sand & gravel	glaciofluvial
MT03-175	8/18/2003	land	84B	UTM NAD83	6300561	582506		forest-mixed	poplar	white spruce	hummock(s)	>5 m	auger	Just south of little channel	1	diemicton	till
MT03-176A	8/19/2003	land	84B	UTM NAD83	6296483	572954		forest-conifer	black spruce	sphagnum	plain	0-2 m	probe	where depths of 190+ are recorded, that equals the maximum length probe.	1	peat	
MT03-176B	8/19/2003	land	84B	UTM NAD83	6296474	572957		forest-mixed	black spruce		undulating	0-2 m	probe	near base of donut, black spruce, not stunted (6-7m) high.	1	diemicton	
MT03-176C	8/19/2003	land	84B	UTM NAD83	6296472	572967		forest-conifer	pine	black spruce	hummock(s)	2-5 m	probe	at base of northeast outside slope of donut, open forest floor.	1	silt	slopewash
															2	diemicton	till
MT03-176D	8/19/2003	land	84B	UTM NAD83	6296462	572978		forest-deciduous	poplar		hummock(s)	>5 m	probe	top of northeastern ridge	1	diemicton	till
MT03-176E	8/19/2003	land	84B	UTM NAD83	6296451	572986		forest-deciduous	poplar	willow	hummock(s)	0-2 m	probe	on northeastern ridge of donut, is a small depression on ridge, still in	1	silt	slopewash
														large poplar stand, but goes down (towards hole) to a wetter willowy area	2	sand	glaciofluvial/lac?
														then wht spruce and then the black spruce bog.	3	diemicton	till
MT03-176F	8/19/2003	land	84B	UTM NAD83	6296445	572995		forest-conifer	white spruce		hummock(s)	0-2 m	probe	on northeast inner edge of donut; dense, tall forest	1	peat	wetland
															2	silt and sand	uncertain
															3	diemicton	till
MT03-176G	8/19/2003	land	84B	UTM NAD83	6296429	573004		forest-conifer	black spruce	sphagnum	hummock(s)	0-2 m	probe	on ne edge of spruce and spaghnum bog	1	peat	wetland
															2	silt	uncertain
MT03-176H	8/19/2003	land	84B	UTM NAD83	6296420	573019		forest-conifer	black spruce	sphagnum	hummock(s)	0-2 m	probe	in middle of donut hole, stunted spruce bog, lots of peat hummocks	1	peat	wetland
															2	silt	uncertain
MT03-176I	8/19/2003	land	84B	UTM NAD83	6296394	573040		forest-conifer	black spruce	sphagnum	hummock(s)	0-2 m	probe	still in middle of spruce bog; donut hole	1	peat	wetland
MT03-176J	8/19/2003	land	84B	UTM NAD83	6296376	573048		forest-conifer	black spruce	sphagnum	hummock(s)	0-2 m	probe	getting near bog edge (still in donut hole)	1	peat	wetland
MT03-176K	8/19/2003	land	84B	UTM NAD83	6296349	573059		forest-conifer	black spruce	sphagnum	hummock(s)	2-5 m	probe	at southeast edge of stunted spruce bog; edge of donut hole.	1	peat	wetland
															2	sand	uncertain
															3	diemicton	till
MT03-176L	8/19/2003	land	84B	UTM NAD83	6296360	573064		forest-deciduous	poplar		hummock(s)	>5 m	probe	on top ridge of donut.	1	diemicton	till
MT03-176M	8/19/2003	land	84B	UTM NAD83	6296343	573082			poplar				probe	at base of donut	1	sand	glaciofluvial
															2	diemicton	till
MT03-176N	8/19/2003	land	84B	UTM NAD83	6296320	573100	other				hummock(s)	0-2 m	short note	similar to nw flank of donut	1	diemicton	till
MT03-177	8/19/2003	land	84B	UTM NAD83	6296004	572769	flat	forest-mixed	poplar	white spruce	plain	0-2 m	auger	at intersection between seismic line that goes to donut	1	sand	glaciofluvial
MT03-178	8/19/2003	land	84B	UTM NAD83	6295973	572229	flat	forest-mixed	black spruce	poplar	undulating	0-2 m	auger	driving back on main trail (e-w seismic line), site is on a small ridge	1	diemicton	till
MT03-179	8/19/2003	land	84B	UTM NAD83	6295913	571220	flat	forest-mixed	poplar	white spruce	plain	0-2 m	auger	just crossed a small channal	1	sand	glaciofluvial
															2	silt	glaciofluvial
															3	diemicton	till
MT03-180	8/19/2003	land	84B	UTM NAD83	6295857	570305	flat	forest-mixed	poplar	white spruce	plain	0-2 m	auger		1	sand	uncertain
MT03-181	8/19/2003	land	84B	UTM NAD83	6295874	570070		forest-conifer	pine		undulating	0-2 m	section	close to the channel edge	1	sand	glaciofluvial
MT03-182	8/19/2003	land	84B	UTM NAD83	6295832	569779	hill flank	forest-mixed	poplar	white spruce	undulating	0-2 m	section	ants nest on surface	1	sand	glaciofluvial
MT03-183	8/19/2003	land	84B	UTM NAD83	6295828	568369	hill flank	forest-mixed	pine	poplar	other	0-2 m	auger	Small section of sand and gravel was present on east flank of channel	1	silty sand	glaciofluvial
MT03-184	8/19/2003	land	84B	UTM NAD83	6295838	567586	hill flank	forest-mixed	poplar	black spruce	undulating	0-2 m	auger	on slight undulations up a rise to the west	1	diemicton	till
MT03-185	8/19/2003	land	84B	UTM NAD83	6295829	566745	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	probe	on edge of meltwater channel	1	diemicton	till
MT03-186	8/19/2003	land	84B	UTM NAD83	6295831	565506	flat	forest-mixed	poplar	white spruce	hummock(s)	0-2 m	probe	small stand of trees, surrounded by dried bog	1	diemicton	till
MT03-187	8/19/2003	land	84B	UTM NAD83	6302059	564819	hill flank	forest-mixed	poplar	white spruce	undulating	0-2 m	drive by	Small undulation on the flank of the hill, with ebundent large clests.	1	diemicton	till
MT03-188	8/20/2003	land	84B	UTM NAD83	6294293	585782	flat	forest-mixed	poplar	white spruce	plain	0-2 m	road cut		1	diemicton	till
MT03-189	8/20/2003	land	84B	UTM NAD83	6293014	586293	flat	forest-mixed	poplar	white spruce	plain	0-2 m	burrow pit	Old vegeteted end water-filled burrow pit	1	diemicton	till
MT03-190	8/20/2003	land	84B	UTM NAD83	6292348	587104	flat	forest-mixed	poplar	white spruce	plain	0-2 m	road cut	small roedcut in ditch	1	diemicton	till
MT03-191	8/20/2003	land	84B	UTM NAD83	6291581	583375	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	section	Possibly old wellsite, or filled-in pit. Few sections visible on edges.	1	diemicton	till
MT03-192	8/20/2003	land	84B	UTM NAD83	6293329	582398	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	section	new wellsite (NCE Resources), section on NW side of wellsite	1	diemicton	till
MT03-193	8/20/2003	land	84B	UTM NAD83	6293480	582866	flat	forest-mixed	poplar	white spruce	undulating	0-2 m	road cut	small roedcut hummock/undulation	1	diemicton	till
MT03-194	8/20/2003	land	84B	UTM NAD83	6291769	584880						0-2 m	road cut	small ditch roadcute	1	diemicton	till
MT03-195	8/20/2003	land	84B	UTM NAD83	6291834	586985	flat	forest-deciduous	poplar		undulating	0-2 m	section		1	diemicton	till
MT03-196	8/20/2003	helicopter	84B	UTM NAD83	6291050	570934	flat	forest-mixed	poplar	black spruce	plain	0-2 m	probe	Old, partially overgrown wellsite	1	diemicton	till
MT03-197	8/20/2003	helicopter	84B	UTM NAD83	6291286	568242	flat	forest-conifer	pine		plain	0-2 m	auger	Partially overgrown old wellsite	1	sand	glaciofluvial
MT03-198	8/20/2003	helicopter	84B	UTM NAD83	6316504	562323	flat	forest-mixed	pine	poplar	undulating	0-2 m	probe	partially overgrown wellsite	1	silty clay	glaciolacustrine
MT03-199	8/20/2003	helicopter	84B	UTM NAD83	6316285	562109	hilltop	forest-mixed	pine	poplar	undulating	2-5 m	probe	walked on a seamic line from wellsite where we landed.	1	diemicton	till
MT03-200	8/20/2003	helicopter	84B	UTM NAD83	6318923	566772					plain	0-2 m	fly by	sendy spot visible from helicopter, surrounded by bog	1	sand	glaciofluvial
MT03-201	8/20/2003	helicopter	84B	UTM NAD83	6316090	573025					ridge(s)	>5 m	fly by	flew over- definite ridge, appears sinuous, can not tell if made of sand.	1	other	uncertain
MT03-202	8/20/2003	helicopter	84B	UTM NAD83	6308890	585245	hilltop				other	>5 m	section	K6 kumberlite outcrop, natural kill zone, plus recently (2003) bulldozed section	1	other	bedrock

APPENDIX B



Location of boreholes for cross-section (Figure 33)

Borehole 8



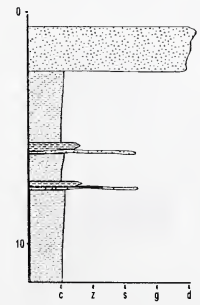
0 to 4 0 m — Till; dark grey-brown, strongly calcareous. Matrix is clayey-silt, coarsens at depth to sandy-silt. Clasts are around 4%, many rotten and lithologies include abundant limestone, igneous material, gneiss, ironstone, quartzite, and minor black shale. Gradational contact with unit below.

4 0 to 33.0 m — Till: light grey to dark grey at depth, non-calcareous. Matrix is a soft and sticky silty-clay. Friable along fractures with a possible paleo AE/B soil transition. Clasts are around 2% and lithologies include igneous material, quartzite, ironstone, minor black shale, minor local sandstone. Some faces are iron-cemented; till is hard and dry.

19.2 m — Clasts likely include olivine, minor sulphide deposits; continue to 26 m. Minor sand lenses occur,

33.1 to 33.5 m — Sand; grey, fine-grained, non-calcareous. Is water-saturated with oxidized vertical fractures and diamicton interbeds.
33.5 to 34.44 m — Till: as above, with numerous olive brown oxidized zones.
34.44 to 35.5 m — Sand: grey, medium to coarse-grained. Is clean and well-sorted 1 till bed of 5cm thickness.
35.5 to 36.0 m — Till: same as above. Drilling stopped due to auger refusal in wet sand.

Borehole 6



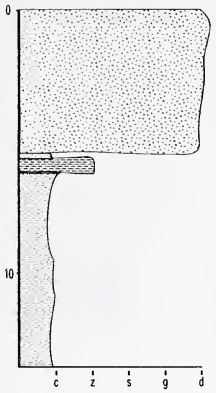
0 to 0.91 m — Fill; core discarded
0 91 to 2.4 m — Till: dark grey-brown, strongly calcareous. Matrix is a plastic silty clay, clay content increasing with depth. Clast lithiologies include abundant rotten limestone, ironstone and minor igneous material.

2.4 to 5.49 m — Mudstone: olive-grey, strongly oxidized. Massive to horizontally bedded at depth with minor silt laminations. Fractured with strong Fe oxidation along fractures

5 49 to 6.1 m — Siltstone and sandstone. grey, fine-grained sand to silt, unoxidized, massive, soft.
6.1 to 7.1 m — Mudstone: dark grey, contains interbeds of silt and fine-grained sand

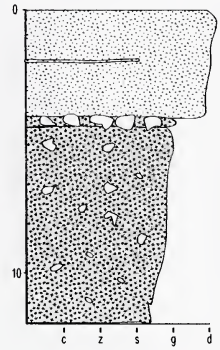
7 1 to 7.6 m — Interbedded siltstone and sandstone. dark grey, massive, soft, with minor clay
7 6 to 11.3 m — Mudstone: dark grey with minor silt and sand interbeds decreasing to massive at depth. Occasional black carbonaceous laminations, non-calcareous

Borehole 5



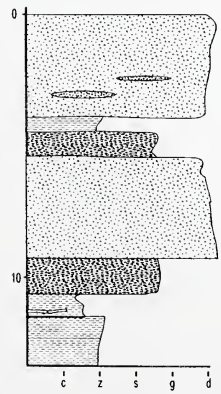
0 to 0.91 m	No recovery
0.91 to 5.49 m	Till: dark grey-brown, strongly calcareous. Matrix is a clayey-silt with common sand. Average is 2% clasts; lithologies include rotten limestone, igneous material, ironstone, quartzite and minor black shale. Oxidation is moderate, creating a mottled appearance.
5.49 to 5.8 m	Mudstone: very dark grey. Is massive, soft and non-calcareous.
5.8 to 6.1 m	Siltstone: dark olive-grey. is massive, clay-rich, oxidized, non-calcareous and friable.
6.1 to 13.11 m	Mudstone: vary dark grey. Horizontally bedded with light grey silty laminations. Non-calcareous, stiff, and is bioturbated at depth.

Borehole 4



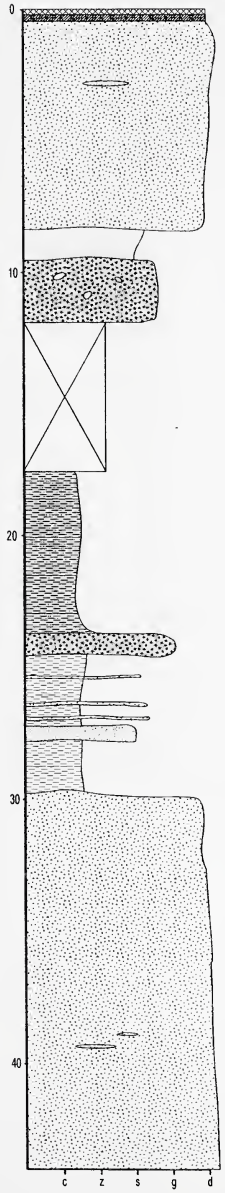
0 to 0.91 m	Fill: core discarded
0.91 to 4.0 m	Till: dark grey-brown, slightly calcareous, slightly oxidized. Matrix is a stiff sandy clayey-silt. Clast lithologies include igneous material, limestone, ironstone, local sandstone. A 2 cm thick, olive brown sand lense occurs at 2.0 m
4.0 to 4.2 m	Boulder lag: gravelly coarse sand with boulders up to 10 cm. Lithologies include gneiss, quartzite and igneous material.
4.2 to 11.89 m	Sand and Gravel: orange-brown, strongly oxizided, medium to coarse sand. Becomes less oxidized and greyer at depth. Sand is generally massive, but poor bedding occurs around 8.5m. Clasts are 10cm at top, and fine to 3-4cm near the base; rounded to angular. Lithologies include igneous material, quartzite, gneiss, Athabasca sandstone, chert and minor rotten limestone.

Borehole 7



0 to 0.05 m	Organic soil
0.05 to 3.9 m	Till: dark grey-brown, moderately calcareous. Matrix is a soft clayey silt to silty clay at depth, containing minor sand lenses of 1 cm thickness at 3m depth. Clast lithologies include igneous material, quartzite and minor limestone. Oxidation is moderate.
3.9 to 4.2 m	Silt: dark brown, mottled orange. Is strongly oxidized, water saturated, soft and loose.
4.2 to 5.3 m	Sand: orange-brown, strongly oxidized, medium to coarse grained. Pebbles up to 4 cm occur, lithologically igneous and quartzite.
5.3 to 9.0 m	Till:black, slightly oxidized. Matrix is a very stiff silty clay; non-calcareous with only 1% clasts. Clast lithologies include black shale, grey sandstone and olivine. Around 7.01m-7.19m numerous olivine rich bands and granules occur. Minor greenish and white weathered kimberlite clasts occur throughout, decreasing at base. Abrupt contact with unit below.
9.0 to 10.7 m	Sandstone: grey-brown, slightly oxidized, very fine-grained, is moderately calcareous with some calcareous laminations dipping at 20°.
10.7 to 11.3 m	Mudstone: dark grey to dark olive-grey. Horizontally bedded with minor siltstone interbeds.
11.3 to 13.11 m	Siltstone: very dark grey, non-calcareous; contains thin interbeds of mudstones; becomes clay-rich at depth.

Borehole 11



0 to 0.3 m	Fill: core discarded
0.3 to 0.4 m	Organic soil
0.4 to 8.2 m	Till: grey-brown, strongly calcareous. Matrix is stiff clayey silt to sandy silt, coarsening upward. Till is moderately oxidized near top, grading to unoxidized at base. 1-2 mm orange sand lens occurs at 2.7 m depth. Clast lithologies include abundant rotten limestone, ironstone, igneous material, shale, local sandstone quartz and chert. Orange-brown mottling occurs at depths greater that 0.9 m. Mottling appears to be the result of concentration of oxidation along fractures.
8.2 to 9.8 m	Sand: grey, coarse, very well sorted. Unit fines downward to medium sand. Clasts include Canadian Shield derived material, igneous material, and quartz. The contact with the overlying till is sharp.
9.8 to 11.9 m	Sand and gravel: clasts up to large cobble in size. Drilling difficult.
11.9 to 17.4 m	No core recovered.
17.4 to 23.8 m	Interbedded silt and clay: dark grey brown in upper to dark brown grey in lower; unoxidized, strongly cal careous. Massive to bedded with distorted bedding above 19.20 m and horizontal bedding below. Massive silt occurs from 23.0 to 23.40 m. Individual interbeds are up to 10 cm in thickness. Lower 10 cm of unit is marked by horizontally bedded silt and fine-grained sand.
23.8 to 24.5 m	Gravelly sand: grey, dirty. Calcareous, with igneous, limestone, quartz and Athabasca sandstone clasts.
24.5 to 29.8 m	Grey to dark grey interbedded clay and silt. Unit varies from moderately to strongly calcareous. Thin (up to 20 cm) layers of diamicton occur. Diamicton at 25.3 m is massive, composed of gravel, sand and clay, is calcareous and contains igneous, ironstone and carbonate clasts. Diamicton layers at 26.4 and 26.8 m are silty sand, granule rich and contain igneous, Athabasca sandstone, carbonate and abundant dark grey shale clasts. A 50 cm thick sand bed is present at a depth of 27.3 m. This bed is grey, strongly calcareous and coarsens downward from very fine grained to grained.
29.8 to 43.6 m	Till: dark grey, non-calcareous, very firm, with a clayey silt matrix. Till is oxidized and iron stained above 36.4 m depth. Clasts include shale, granite, Athabasca sandstone, carbonates, mudstones, shale and shell fragments. Shell fragments abundant lower in unit. Sulphide nodule (<1mm) is present at 36.0 m depth. Clast content increases with depth, and Athabasca sandstone and black shale are more common at greater depth. 6 cm calcareous siltstone clast is present at ~36 m depth, and clasts >3 cm are common. Sand lenses are present at ~38 m depth. Matrix coarsens with depth up to silt to fine sand.

NTS 84B/13
SURFICIAL GEOLOGY

570000m.E

580000m.E

116° 00'

Rg 13

Rg 12

57° 00'

Tp 92

Tp 91

6310000m.N

Sawn Lake

580000m.E

Rg 11

Rg 10 W5

590000m.E

115° 30'

57° 00'

Tp 92

Tp 91

6310000m.N

UNIT

QUAT
HOLO

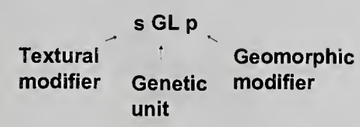
PLEIS

PRE-C

UNIT	UNIT NAME	DESCRIPTION AND GENESIS
QUATERNARY		
HOLOCENE		
O		**ORGANIC DEPOSITS:** Undifferentiated peat (woody to fibrous muck) occurring in undifferentiated wetlands; commonly underlain by fine-grained, poorly drained glaciolacustrine deposits; includes marshes, swamps, bogs and fens.
OB		**Bog peat:** Occurs in a peatland with a fluctuating water table and commonly a raised surface; peatland surface is dominated by sphagnum mosses, shrubs and short, stunted trees.
OF		**Fen peat:** Occurs in a peatland with water table at surface and slow internal drainage; peatland surface is dominated by sedges, with grasses and reeds near local pools, sparsely treed.
C		**COLLUVIAL DEPOSITS:** Materials that have reached their present position as a result of direct, gravity-induced movement; commonly occur as slope and slump deposits confined to valley slopes and floors; include pre-existing bedrock, till, glaciolacustrine, glaciofluvial and eolian sediments, generally poorly sorted.
F		**FLUVIAL DEPOSITS:** Sediments transported and deposited by streams and rivers; synonymous with alluvial. Include well-sorted stratified sand, gravel, silt, clay and organic sediments occurring in channel and overbank deposits (e.g., postglacial floodplains, terraces, fans and deltas).
L		**LACUSTRINE DEPOSITS:** Sediments deposited in and adjacent to recent lakes; offshore sand, silt and clay; littoral (nearshore) beaches and bars of sand, silt and minor gravel; minor organic deposits.
E		**EOLIAN DEPOSITS:** Wind-deposited sediments; well-sorted, medium to fine-grained sand and minor silt (loess); generally massive to locally crossbedded or ripple laminated; include both active and vegetated deposits.
PLEISTOCENE		
LG		**GLACIOLACUSTRINE DEPOSITS:** Primarily fine-grained, distal sediments deposited in or along the margins of glacial lakes, including sediments released by the melting of floating ice. Include laminated (rhythmically bedded) to massive fine-grained sand, silt and clay, and may contain ice-rafted stones.
LGI		**Glaciolacustrine ice contact deposits:** Rhythmites of laminated silt and fine sand deposited in ice-walled supraglacial lakes.
FG		**GLACIOFLUVIAL DEPOSITS:** Sediments deposited by glacial meltwater streams as subaerial or subaqueous outwash. Include sand and gravel, often stratified, minor silt, and may show evidence of ice melting (slumped structures). Features include meltwater channels, kettle holes, terraces and minor ice-contact sediments.
FGI		**Ice-contact sediments:** Sediments deposited by glacial meltwater streams in direct contact with glacial ice, either in front of (kame terraces) or within (eskers, crevasse ridges) glacial ice. include massive to stratified, poorly to moderately sorted, coarse sediments (predominantly pebble gravel and coarse sand, locally till) and may show evidence of ice melting (slumped structures).
M		**MORAINE:** Nonsorted diamicton (till) deposited directly by glacial ice, consisting of a mixture of clay, silt, sand and minor pebbles, cobbles and boulders. Locally, this unit may contain blocks of bedrock, pre-existing stratified sediment, till and lenses of glaciolacustrine and/or glaciofluvial sediments.
MS		**Stagnant ice moraine:** Material resulting from the collapse and lateral movement of englacial and supra-glacial sediment in response to melting (ablation) of stagnant ice at the ice margin; sediment is mainly diamicton, but locally includes stratified sediments of glaciolacustrine or glaciofluvial origin. Characterized by low to high-relief hummocky topography.
PRE-QUATERNARY		
RT		**UNCONSOLIDATED FLUVIAL GRAVELS:** Predominantly well-sorted quartzite and chert gravel and cobbles; Cordilleran source, Paleogene (Tertiary) to Quaternary.

UNIT NOTATION

Example: sandy GLACIOLACUSTRINE plain



Textural Modifier

Textural characteristics may be applied to the terrain classification as a prefix based on field observations or by inference from distinctive genesis and/or morphology. When two modifiers are given, the second letter is the dominant texture, with the first letter indicating the secondary texture; i.e., sc for sandy clay.

g = gravel
s = sand
$ = silt
c = clay

GEOMORPHIC MODIFIERS

c	**crevasse fill**	ice-contact ridges, ice-squeeze deposits and linear forms deposited by meltwater in stagnant ice
d	**doughnut rings and ridges**	circular hummocks with a central depression, plateau mounds and brain-like pattern ridges, low to moderate relief
e	**eroded**	planar surface eroded by glacial meltwater, often capped by a boulder lag deposit and/or thin deposit of sand and gravel
h	**hummock**	assemblage of approximately equidimensional hills and hollows; moderate to high relief (commonly greater than 2 m)
p	**plain**	deposit greater than 2 m thick; commonly masks geomorphic pattern of underlying deposits; flat to gently rolling topography (commonly less than 2 m relief)
r	**ridged**	one or more parallel or subparallel, convex, linear morphological elements with a length-to-width ratio greater than 2; low to high relief
s	**slumped**	landslide blocks, slope failure debris
t	**terrace**	terrace bench cut by either meltwater or wave action; antiplanation terrace, kame terrace
u	**undulating**	low-relief rolling terrain; swell and swale topography
v	**veneer**	thin mantle of unconsolidated material too thin to mask the minor irregularities of the surface of the underlying material; it ranges in thickness from 10 cm to 1 metre and may be discontinuous
y	**dissected**	channelled or dissected by glacial meltwater flow; dissected terrain by Holocene fluvial activity

Stratigraphic Sequence

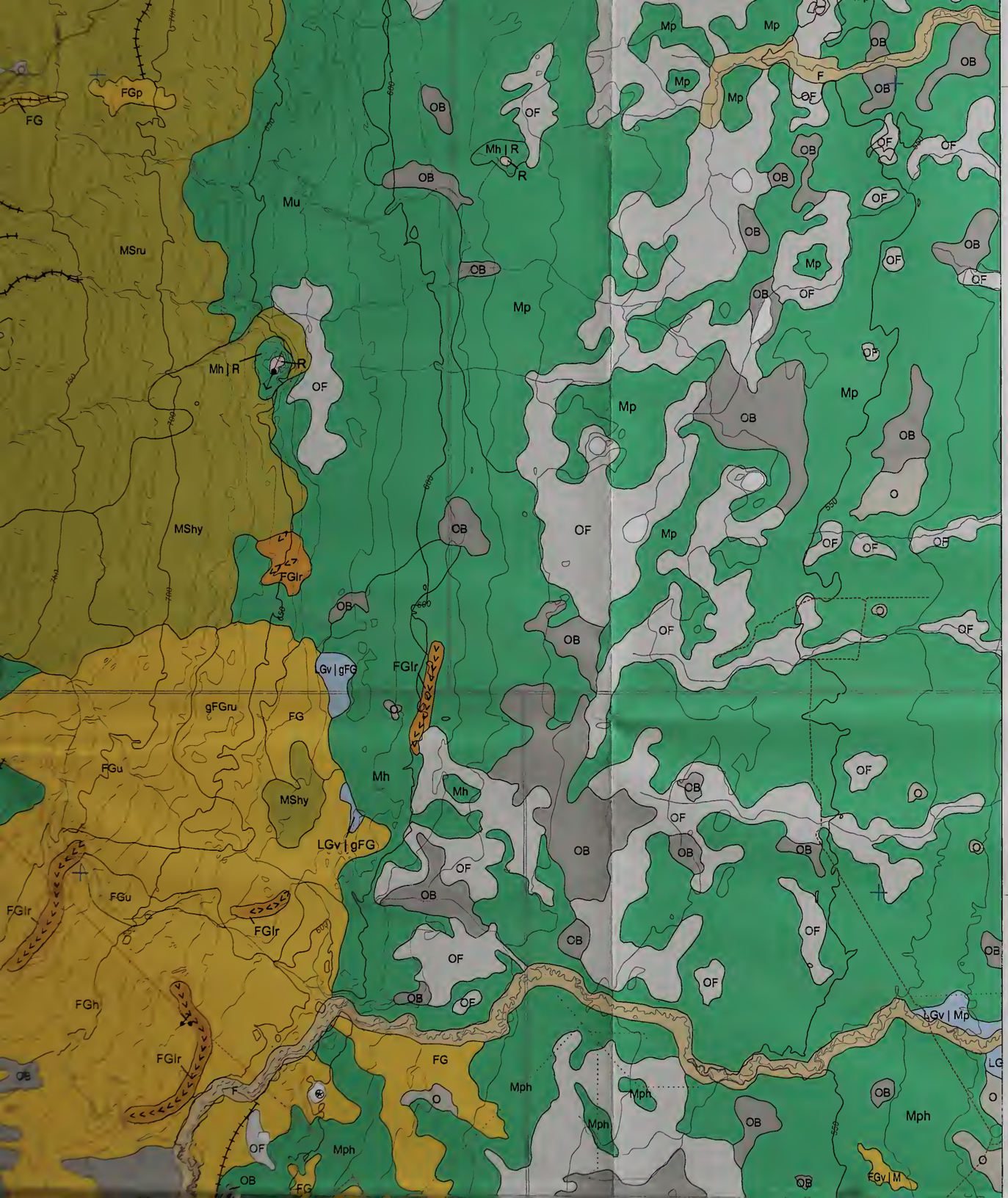
Where materials of different origin or textures are known to be superimposed or can be confidently inferred, the sequence is indicated in conventional order using vertical separators, such as:

Tp 90

Tp 91

6310000m.N

6310000m.N



LGl **Glaciolacustrine ice contact deposits:** Rhythmites of laminated silt and fine sand deposited in ice-w supraglacial lakes.

FG **GLACIOFLUVIAL DEPOSITS:** Sediments deposited by glacial meltwater streams as subaerial or sub outwash. Include sand and gravel, often stratified, minor silt, and may show evidence of ice melting (s structures). Features include meltwater channels, kettle holes, terraces and minor ice-contact sedime

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PRE-QUATERNARY

RT **UNCONSOLIDATED FLUVIAL GRAVELS:** Predominantly well-sorted quartzite and chert gravel and Cordilleran source, Paleogene (Tertiary) to Quaternary.

R **BEDROCK:** Undifferentiated; may include clastic sedimentary rock, shale, kimberlite and/or coal.

SYMBOL LEGEND

- Esker, direction of paleoflow unknown
- Esker, direction of paleoflow indicated
- Meltwater channel (minor)
- Meltwater channel (major)
- Eolian forms; dune ridges
- Crevasse filling
- Ice contact slope
- Beach or strandline
- Minor moraine ridge; De Geer, Rogen, ribbed, washboard (minor)
- Crag and tail
- Striation (direction known)
- Kettle
- Bedrock outcrop
- Gravel and/or sand pit

BASEMAP LEGEND

- Gravel
- Unimproved
- Truck-trail
- UTM, Zone 11 Grid — 430000m.E
- Contour, intervals 10 metres

LGl **Glaciolacustrine ice contact deposits:** Rhythmites of laminated silt and fine sand deposited in ice-walled supraglacial lakes.

FG **GLACIOFLUVIAL DEPOSITS:** Sediments deposited by glacial meltwater streams as subaerial or subaqueous outwash. Include sand and gravel, often stratified, minor silt, and may show evidence of ice melting (slumped structures). Features include meltwater channels, kettle holes, terraces and minor ice-contact sediments.

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SYMBOL LEGEND

Esker, direction of paleoflow unknown	<><><>
Esker, direction of paleoflow indicated	>>>>>>
Meltwater channel (minor)	
Meltwater channel (major)	
Eolian forms; dune ridges	
Crevasse filling	
Ice contact slope	
Beach or strandline	
Minor moraine ridge; De Geer, Rogen, ribbed, washboard (minor)	
Crag and tail	
Striation (direction known)	
Kettle	
Bedrock outcrop	×
Gravel and/or sand pit	

BASEMAP LEGEND

Gravel	
Unimproved	
Truck-trail	
UTM, Zone 11 Grid	430000m.E
Contour, intervals 10 metres	

		greater than 2 m)
p	**plain**	deposit greater than 2 m thick; commonly masks geomorphic pattern of underlying deposits; flat to gently rolling topography (commonly less than 2 m relief)
r	**ridged**	one or more parallel or subparallel, convex, linear morphological elements with a length-to-width ratio greater than 2; low to high relief
s	**slumped**	landslide blocks, slope failure debris
t	**terrace**	terrace bench cut by either meltwater or wave action; antiplanation terrace, kame terrace
u	**undulating**	low-relief rolling terrain; swell and swale topography
v	**veneer**	thin mantle of unconsolidated material too thin to mask the minor irregularities of the surface of the underlying material; it ranges in thickness from 10 cm to 1 metre and may be discontinuous
y	**dissected**	channelled or dissected by glacial meltwater flow; dissected terrain by Holocene fluvial activity

Stratigraphic Sequence

Where materials of different origin or textures are known to be superimposed or can be confidently inferred, the sequence is indicated in conventional order using vertical separators, such as:

'sLGv | Mp' Thin sandy glaciolacustrine sediment deposited on morainal plain

Morphologic Overprint

Where a sequence of geomorphic processes has produced a multi-aspect or compound terrain fabric, the geomorphic modifier suffixes are appended in the inferred order of super position. 'Mpry' means that a plain of till has been moulded into ridge forms and finally dissected by modern streams. 'FGphr' means that a glaciofluvial plain has been discontinuously covered by ice-contact hummocks and ridges.

Acknowledgements:

The Alberta Geological Survey, under the Alberta Mineral Development Strategy, carried out field work and airphoto interpretation in 2003. This project was also part of the Northern Resources Development Project 4450 (Shallow Gas and Diamond Opportunities in Northern Alberta and British Columbia 2003-2007) of the Geological Survey of Canada. Field visits and sample data collected by Roy Eccles (1998), Mark Fenton (2001), John Pawlowicz (2002), Glen Prior (2002) and Beth McClenaghan (2003) were made available to the authors to augment field observations. Glen Prior and John Pawlowicz provided unpublished data of previous work conducted in the area. Digital cartography and GIS were compieted by Monica Price and Natasha Clarke. Base data provided by Spatial Data Warehouse Ltd.

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Prior, G.J., Paulen, R.C., Pawlowicz, J.G. and Fenton, M.M. (2005): Kimberlite-indicator mineral till survey of the Sawn

Tp 90

Tp 89

56° 45'

116° 00'

Rg 13

Rg 12

Rg 11

570000m.E

580000m.E

Published 2006

Copies of this map may be obtained from:

Information Sales Office
Alberta Geological Survey
Telephone: (780) 422-3767
Website: www.ags.gov.ab.ca

Map 314

Surficial Geology of the Sawn Lake Area (NTS 84B/1

Geology by: M.S. Trommelen, R.C. Paulen and J.A. Weiss

EUB
Alberta Energy and Utilities Board

AGS
Alberta Geological Survey

Shallow Gas & Diamond Opportunities in Northern Alberta and British Columbia 2003 - 2007

Scale 1:50 000

1 0 1 2 3 4 5 kilometres

1 0 1 2 3 miles

Projection: Universal Transverse Mercator
Datum: North American Datum, 1983

Tp 90

Tp 89

56° 45'

115° 30'

Rg 12

Rg 11

580000m.E

Rg 10 W5

590000m.E

Map 314

Surficial Geology of the Sawn Lake Area (NTS 84B/13)

Geology by: M.S. Trommelen, R.C. Paulen and J.A. Weiss

Scale 1:50 000

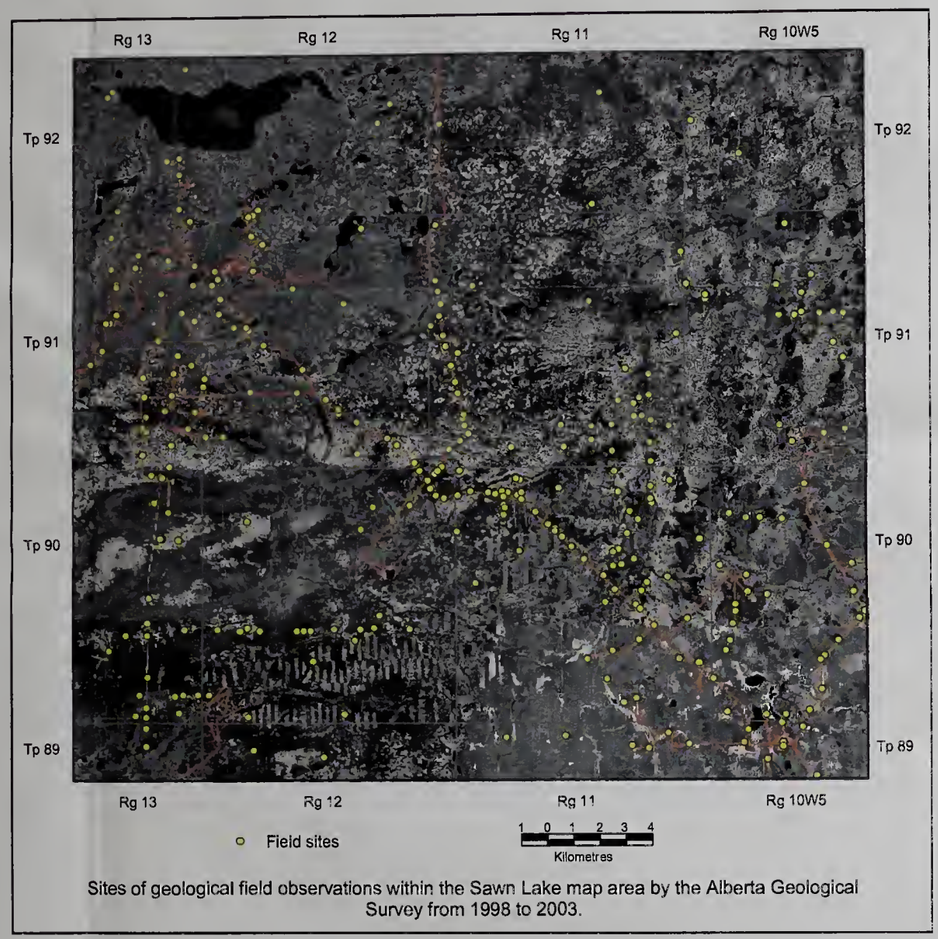
1 0 1 2 3 4 5 kilometres

1 0 1 2 3 miles

Projection: Universal Transverse Mercator
Datum: North American Datum, 1983

UTM, Zone 11 Grid + 430000m.E

Contour, intervals 10 metres



Sites of geological field observations within the Sawn Lake map area by the Alberta Geological Survey from 1998 to 2003.

Pawlowicz, J.G., Fenton, M.M. and Weiss, J.A. (2005): Auger core lithologs, Sawn Lake area, southern Buffalo Head Hills, Alberta; Alberta Energy and Utilities Board, EUB/AGS Geo-Note 2005-07, 48 p.

PhotoSat Information Ltd. (2002): Alberta IRS 2002 mosaics, 5 m orthorectified remote-sensing imagery, GeoTiff derived from MrSID, Photosat Information Ltd.

Prior, G.J., Paulen, R.C., Pawlowicz, J.G. and Fenton, M.M. (2005): Kimberlite-indicator mineral till survey of the Sawn Lake area (NTS 84B/13), southern Buffalo Head Hills, Alberta; Alberta Energy and Utilities Board, EUB/AGS Geo-Note 2005-02, 103 p.

Recommended citation:

Trommelen, M.S., Paulen, R.C. and Weiss, J.A. (2006): Surficial geology of the Sawn Lake area (NTS 84B/13); Alberta Energy and Utilities Board, EUB/AGS Map 314, scale 1:50 000.